# THE PRINCIPLES OF APPLIED ZOOLOGY

ROBERT A. WARDLE

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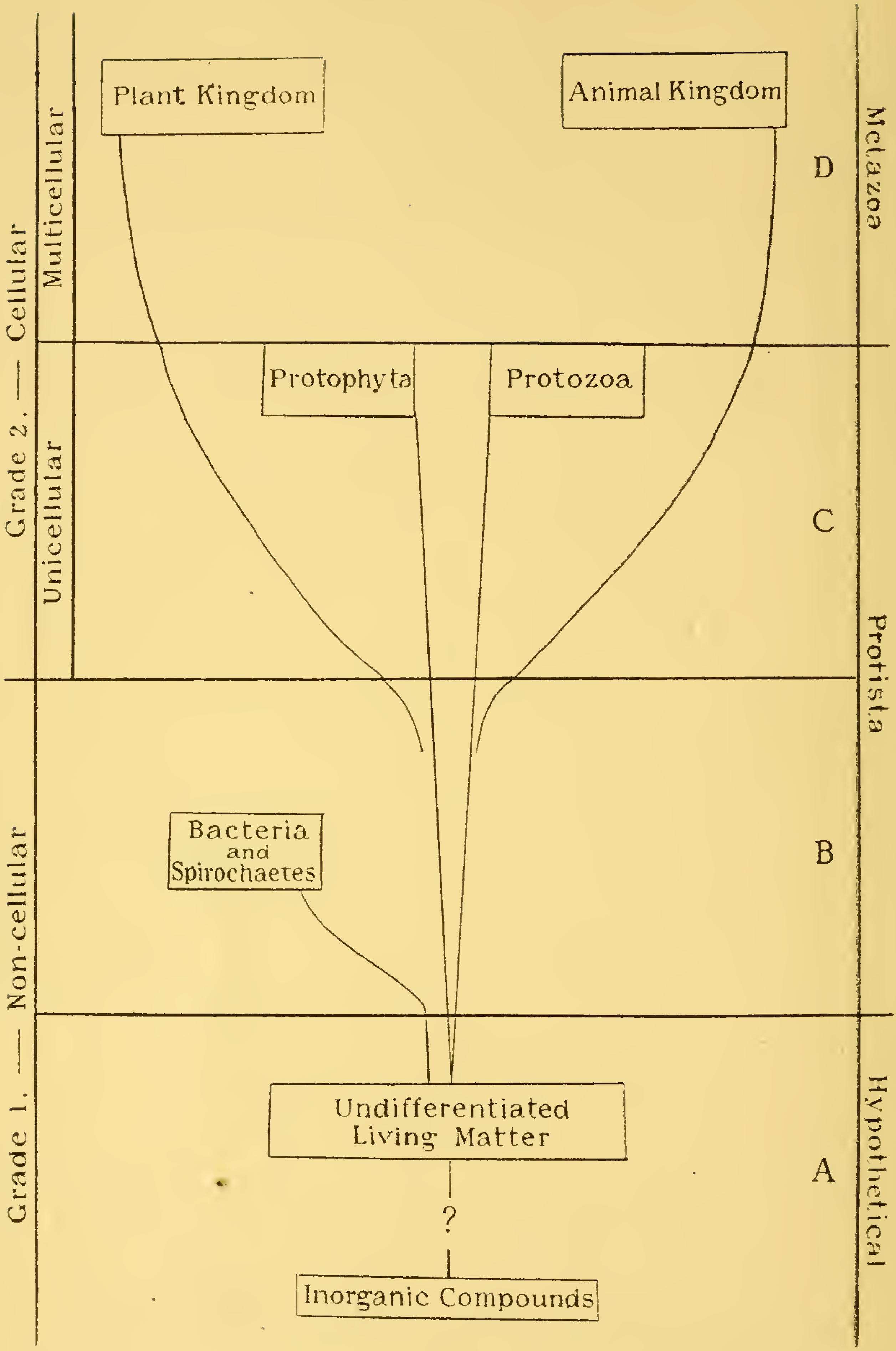


The Classification of Living Creatures.

# THE PRINCIPLES OF APPLIED ZOOLOGY


BY
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# PREFACE

The difficulties experienced by the unfortunate fisherman of Bagdad, in persuading a djinn to retire within the limited confines of a brass bottle, were scarcely more pronounced than those which face the zoologist who attempts to compress the vast accumulation of applied zoological knowledge into a summary, sufficiently restricted to pass into the brass bottle of the publisher's limits, yet sufficiently informative to be of value and interest not only to the student of zoology, but to the student of agriculture, or of medicine, and to the general reader.

The difficulties of the task account possibly for the fact that previous works dealing with Economic or Applied Zoology as a whole, can be counted on the fingers of one hand, whereas as regards component branches—Agricultural Entomology, Medical Entomology, Sea Fisheries, Livestock Breeding, or even Fur Farming—books are numerous and, on the whole, good.

Such a general summary is possible within compact limits, only if discussion and description be limited to general problems and to general principles. To the general reader, a mass of detail concerning the classification, morphology, or economic control of animal life is not essential to his comprehension of the fundamental problems which concern his food supply, clothing, health, and so on. As regards the student, whether of agriculture, medicine, or zoology, desirous of more detailed information, the comprehensive bibliography which concludes the book should be a copious source from which to select according to his needs.

The author must acknowledge gratefully the advice and active help of the late Mr Philip Buckle of the University of Durham, and of Dr Geoffrey Lapage of the University of Manchester, in the arrangement of material; the help of Miss Ruth Charlesworth, Miss May E. Goodwin, and Miss Sybil Wildman and Miss Mary Parkes of the University of Manchester, and of Mr H. Gray and Mr G. A. Mail of the University of Minnesota, in the preparation of the illustrations; and the generous help afforded by the following in granting permission for the use of figures from their publications :—

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University of Manitoba,
*September* 1928.

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# THE PRINCIPLES OF APPLIED ZOOLOGY

## PART I

## MEDICAL AND VETERINARY ZOOLOGY

### CHAPTER I

### PROTOZOA : The Biology and Classification

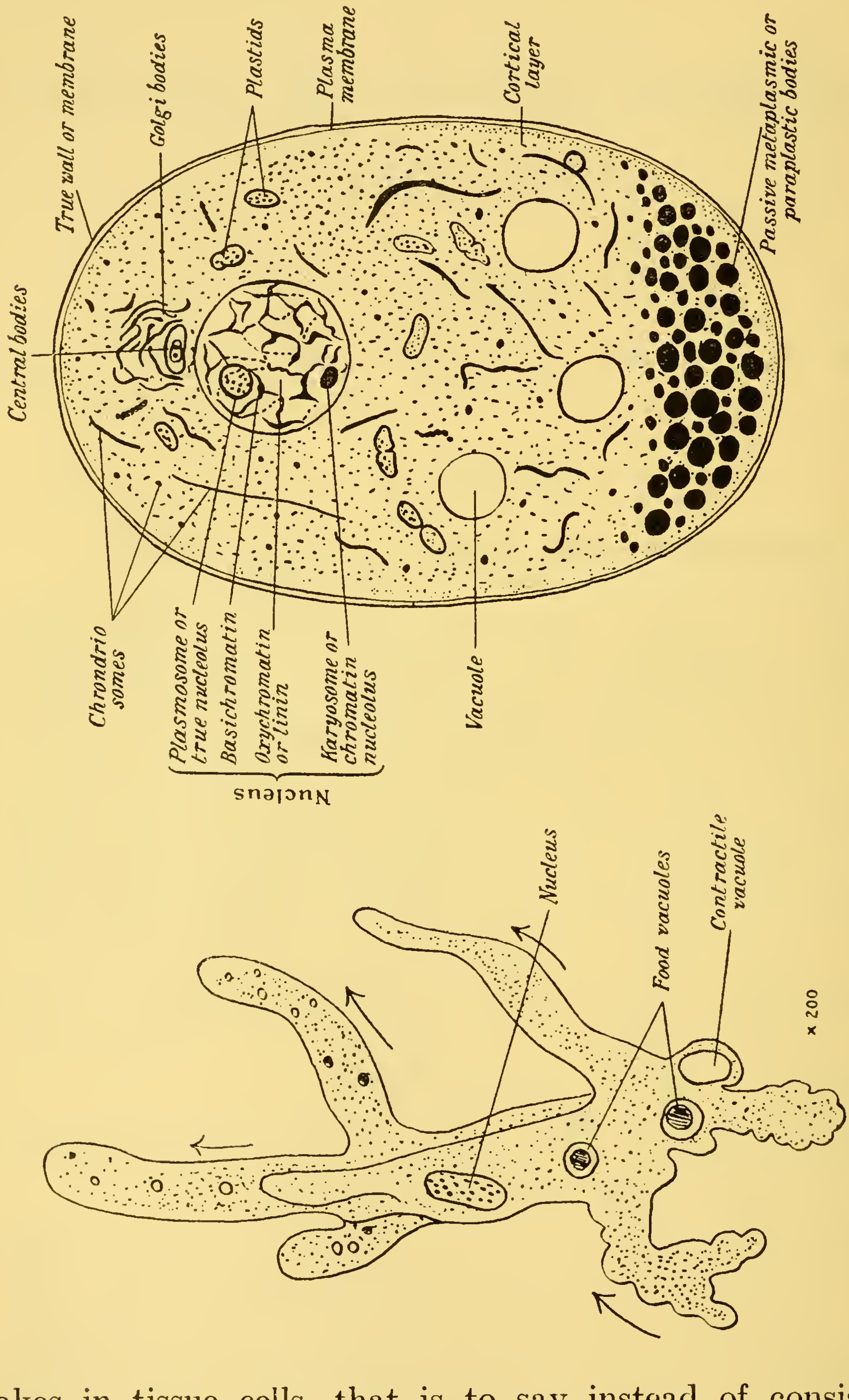
THE aspect of biology which concerns itself with the micro-organisms of stagnant water, of infusions, of the animal gut, and so forth, owes much to the conception of animal and plant structure referred to generally as the **cell theory**. Once the old idea that a cell was an enclosed portion of an animal or plant tissue, comparable to a compartment of a honeycomb, had become superseded by the more rational view that regards it as a mass of protoplasm controlled by a complex cell organ, the nucleus, it became possible to draw direct comparisons between the cell units of animal and plant tissues and the individuals of that extensive assemblage of microscopic creatures formerly labelled vaguely as "infusoria" or "animalculæ," but now generally referred to as **Protista.**

It became possible, in fact, to postulate the existence of **unicellular organisms** and to compare their biological features with those of the accepted animals and plants.

A typical Protiston, such, for example, as the common laboratory type *Amœba*, if not possessing necessarily a cell wall nor a peripheral coagulation of the protoplasm, is essentially a mass of protoplasm under the control of a nuclear structure which in many cases is almost indistinguishable from the nucleus of a tissue cell. Reproduction, too, may be like that of the tissue cell, a simple division of the individual into two, preceded by a complicated series of nuclear changes.

There are, however, important differences between the

Protiston and the tissue cell. In the first place, the protistan nucleus instead of being of the *granular* type, the form it usually




General Diagram of a Cell. (After Wilson.)

Amœba Proteus.

FIG. 1.—The Protistan and Metazoan Types of Cell.

takes in tissue cells, that is to say instead of consisting of minute fragments of stainable *chromatin* distributed over a non-stainable network of *linin*, may be of the *karyosomatic* or *vesicular* type (Fig. 1) in which the greater part of the chromatin

forms a single central mass referred to as the karyosome or chromatin nucleus, and situated in a vacuole containing fluid.

In the second place, the chromatin of the Protiston is not always confined to the nucleus but may occur also as extra-nuclear granules in the cytoplasm; that is to say, in the cell substance outside the nucleus. Such granules, derived from the nucleus, are termed "*chromidia.*" In certain phases of the protistan life-cycle, the whole nuclear structure may be represented by such scattered granules rather than by a central aggregation of them. In bacteria, such a *chromidial condition* is the rule. In other Protista, however, such scattered granules indicate a departure from the normal. They may represent products of cell metabolism, derived either from the nucleoplasm or from the cytoplasm; they may be decomposition products of the nucleus in a dying or dead cell; or they may represent a stage in the formation of a number of nuclei from a single nucleus prior to cell division.

The coexistence of chromidia with a definite nucleus has been explained by Hertwig on the hypothesis that the relation of nucleus to cytoplasm, in other words $\frac{N}{C}$, tends to be a constant; so that if the nuclear matter increases in bulk faster than the cytoplasm does, the $\frac{N}{C}$ ratio is maintained by the nucleus giving up its surplus chromatin in the form of chromidia; if, however, the ratio be disturbed by excess of cytoplasm, the absorption of chromidia by the nucleus will bring about adjustment.

In the third place, the resemblance between Protiston and tissue cell is morphological rather than physiological. The Protiston is physiologically an independent entity, comprising within itself all the various metabolic activities—locomotion, assimilation, growth, excretion, reproduction, and so forth—which are characteristic of the phenomenon called life.

The typical tissue cell, on the other hand, is a specialised unit, possibly excretory or protective or absorptive or sensory, but never physiologically complete, never capable of living a life apart from its co-partners in the metazoan body. Now these differences which do undoubtedly exist between Protista and tissue cells have caused some biologists to criticise the comparison made above between a Protiston and a metazoan tissue cell. They assert, in fact, that Protista are not comparable with Metazoa; that they are non-cellular and represent

a type of organisation quite different from that seen in multicellular organisms; and that they are not by any means simple, and not necessarily primitive.

It seems clear that this view regarding non-cellularity is based upon two misconceptions, namely, that a cell is a subdivision of an animal or plant tissue, and that the terms *homology* and *analogy* are identical.

It can be conceded that if the term cellular implies subdivision, then the protistan body, since it is not subdivided, is non-cellular; but the view that laid stress upon the cell wall and regarded a cell as a subdivision, has long been replaced by the conception of a cell as a unit mass of protoplasm controlled by a nuclear structure, a dynamic centre as essential to it as the brain is to the body of man. A cell wall is not obligatory, nor need a cell be a subdivision, unless the ovum or spermatozoon of an animal are also to be regarded as non-cellular. Again, the statement that the Protiston is homologous to a tissue cell implies, according to the accepted biological definition of homology, merely morphological and embryological resemblance. It does not imply functional resemblance, as would the use of the term analogy, and even the most ardent advocate of unicellularity would not assert that Protista were analogous to tissue cells. Unicellularity implies in fact that a Protiston resembles morphologically and embryologically the cell unit of a multicellular tissue, but physiologically it must be compared to the whole multicellular organism of which the tissue forms a part.

In structural detail, among Protista, there is a considerable range of variation. There are forms which, although undoubtedly not so simply constructed as was formerly supposed, do seem to comprise merely a nuclear mass embedded in a non-differentiated cell protoplasm. There are also forms which possess definite cytoplasmic structures, conveniently referred to as "organelles," which carry out the various functions of the organism, locomotion or assimilation, or so forth.

Broadly speaking, the way of life is either plant-like or animal-like.

The protistan individual may behave in every respect like a minute plant, may have a rigid cell wall of cellulose, may be immobile, may contain the pigments chlorophyll or xanthophyll which enable the plant to synthesise its carbohydrate requirements from the atmospheric carbon dioxide and the soil water. That is to say, the Protiston may be **holophytic.**

On the other hand, however, such pigments may be lacking,

and the organism, unable to avail itself of solar energy, will either have to ingest the insoluble proteins and carbohydrates and fats of animal and plant tissues and deal with them by the help of its own internal ferments, or will have to avail itself of the soluble food-stuffs — amino acids and sugars — produced by bacterial action or by the action of ferments poured out of itself upon animal and plant tissues.

That is to say, it will have to be **holozoic,** a devourer of other organisms, or it will have to be **saprobiotic,** a frequenter of decaying plants or animals, or it will have to be **parasitic,** an absorber of the nutritive fluids of other plants or animals. Quite obviously a holophytic, saprobiotic, or even parasitic Protiston is not absolutely in need of a mouth nor of organelles for catching food or for rapid locomotion. The holophytic organism requires the necessary light-absorbing pigment—chlorophyll, xanthophyll, hæmatochrome—whatever it may be, and requires in addition, if environmental conditions be favourable, merely a sufficiency of water, mineral salts, and sunlight. Its cell wall can be of rigid cellulose without any aperture whatever for food ingestion.

The saphrophytic organism can take in its nutritive requirements in soluble form by osmotic transference through the outer protoplasmic layer, and requires no mouth. Even many holozoic forms manage perfectly well without definite apertures for food ingestion. *Amœba*, for example, can take in food particles through any portion of its body surface ; the food particles, if in contact with the amœba, may be sucked into the body without apparently any movement on the part of the animal, but usually the amœba either flows around the food particle and engulfs it, or sends out finger-like processes of its body substance, so-called " pseudopodia," which encircle and absorb the prey.

Now the amœba is a crawling organism, and its scope as a predatory animal is consequently limited.

A successful predator must be speedy ; in an aquatic medium it must be a fast swimmer ; but organelles for fast locomotion involve the presence of a firm, limiting cell wall, a morphological condition which prohibits food ingestion at any point except through a definite mouth or body-wall pores.

Since, therefore, a sufficiency of suitable food is essential to the organism, the evolution of organelles of locomotion has been accompanied in Protista by the evolution of a definite mouth and of structures for inducing food particles to enter such a mouth.

The evolution of speed, in advance of the condition existing in the amœboid type of organism, has been accomplished by the acquisition of one or other of two very different types of locomotor organelles.

In one large group of Protista the locomotor structures consist of one or more **flagella,** whip-like extensions of the protoplasm which can carry out lashing movements. In another group of Protista occur slender, hair-like organelles termed **cilia.**

Such cilia are usually very numerous, forming as it were a furry coating to the organism, and are so co-ordinated as to produce definite waves of motion, each cilium in a longitudinal row contracting slightly later than the one in front of it.

**Reproduction** in Protista is an extremely complicated process. It may be noted that there is always some form of body cleavage into two or more daughter individuals. That is to say, the whole or the greater bulk of the parent body is used up in the process of producing progeny. Such division is always preceded by division of the nuclear apparatus. The nuclear division may be followed almost immediately by the division of the individual into two, a process termed **binary fission,** or the nuclear divisions may go on for some time unaccompanied by cell division, so that a multinucleate condition results; but ultimately the body breaks up into as many daughter individuals as there are nuclei, a process which is termed **multiple fission.**

The life-cycle may be one of several types.

Reproduction may be **asexual,** the organism multiplying by binary or multiple fission.

It may be **sexual,** the binary or multiple fission being preceded by a process of fusion between two individuals; such fusion may be temporary or it may be permanent; the individuals may be morphologically identical or may be greatly dissimilar, but there is always an interchange of chromatin or of cytoplasm or of both between the two individuals; the process is termed **conjugation.**

There may be a sexual or conjugation phase interrupting a series of asexual phases of reproduction, or there may be definite alternation of one sexual phase with one asexual phase.

**Classification of Protista.**—It is usual to subdivide the Protista into Bacteria, Protozoa, and Protophyta. These are purely terms of convenience. In fact there are many objections to such subdivision.

Bacteria, admittedly, are readily separated from the others,

but it is extremely difficult, if not actually impossible, to draw a hard and fast line between the other two groups. It is easy to assign to the plant kingdom any Protiston which has a formed nucleus and cell wall of cellulose, which possesses chlorophyll or an allied pigment, and which lacks organelles of locomotion and food prehension.

Similarly, it is easy to group with the animals all Protista that possess a formed nucleus, a mouth and locomotor organelles, and which are holozoic.

There will still remain, however, a large number of forms which cannot properly be classed either with Protozoa or with Protophyta; forms in which a firm cell wall and chlorophyll pigment are accompanied by eye spots and locomotor organelles.

To create for such debatable creatures a separate subdivision, such as Haeckel suggested when he divided unicellular organisms into Protozoa, Protophyta, and Protista, would only postpone the difficulty. There would still remain the difficulty of deciding whether a creature is a plant, an animal, or a Protiston; the use of the term Protista in such a manner would merely create three alternatives as against the original two.

Using the term **Protozoa**, therefore, to comprise unicellular organisms where a definite nucleus is present and where metabolism is *usually* of the animal type, we may divide the group into four classes.

The **Sarcodina** are comparatively large forms where no definite cell wall is present, and in which locomotion is carried out by temporary extrusions of the living protoplasm termed **pseudopodia.**

Speaking very generally, there are two types of sarcodine structure :—

(*a*) The Rhizopod type, represented by such genera as *Amœba*, *Arcella*, *Difflugia* of fresh waters and by the *Foraminifera* of the high seas, where the pseudopodia are either blunt and finger-like in form, or form an irregularly branching network; this type is an adaptation to a creeping existence either upon a muddy pond bottom or upon a surface film.

(*b*) The Actinopod type, represented by the *Heliozoa* of fresh water and the *Radiolaria* of the high seas, in which, as an adaptation to a pelagic life, the pseudopodia are stiff, radially arranged, and unbranched.

The **Mastigophora** comprise an enormous range and variety of forms which have explored every biotic resource; very many possess chlorophyll and are holophytic; other forms,

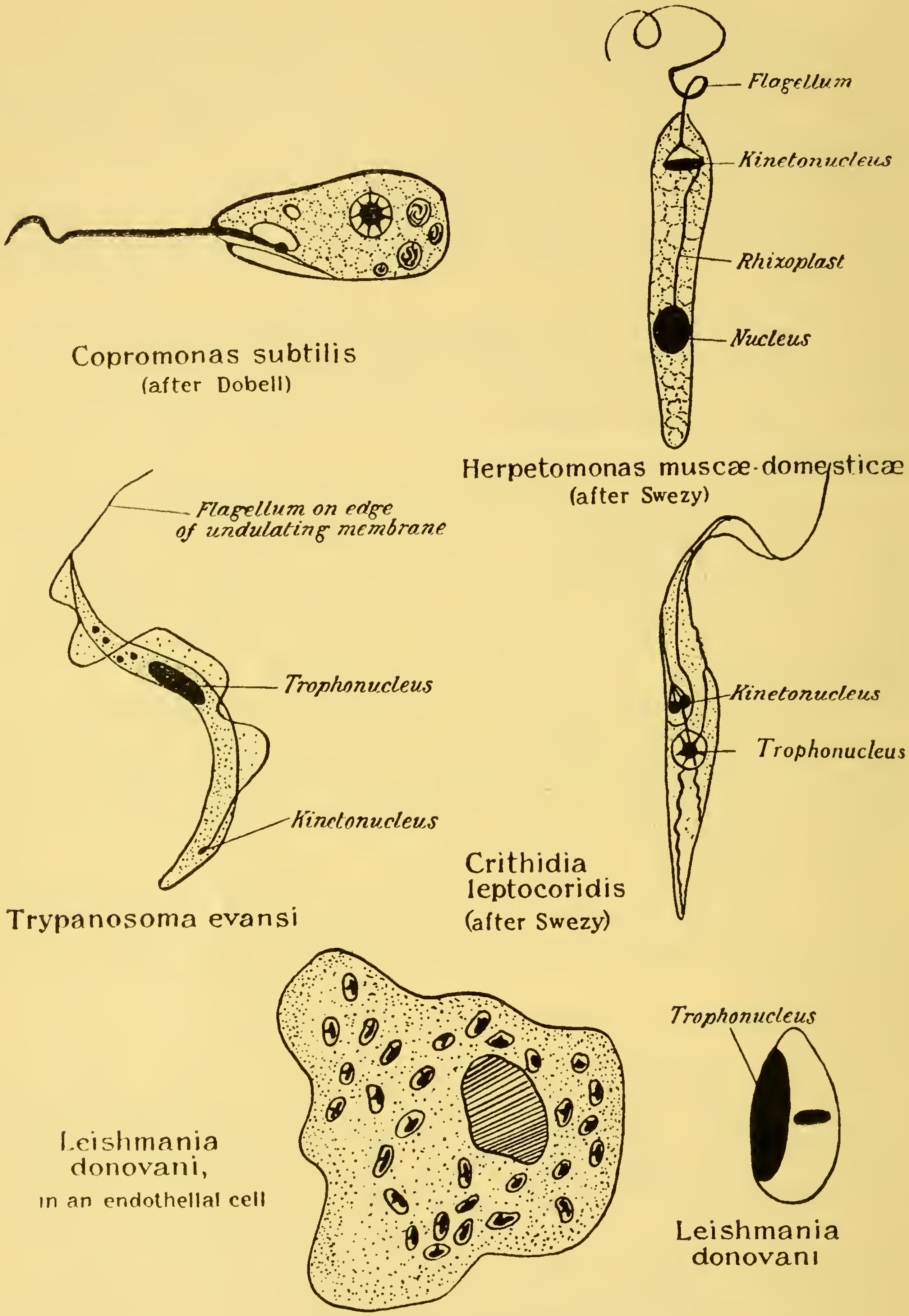



Fig. 2.—Types of Mastigophora.

almost indistinguishable from these, are both holophytic and holozoic; yet others, lacking chlorophyll, are saprobiotic and swarm in sewage, animal excretions, decaying plant

infusions, and the like. Many such forms have passed from this sphere of action to establish themselves in the animal gut, or have even adapted themselves to a life in the animal blood system.

This multifarious assemblage of creatures agrees in that its members lash their way through a medium, which is always fluid and sometimes viscid, by the aid of one or more "flagella," the basal attachment of which generally necessitates the presence of a firm, rigid wall cell, and this again precludes the ingestion of food at any point in the animal's body surface except through definite openings. Either a short funnel-like mouth is present or there is no definite mouth at all, and the nutriment, in this case fluid, is absorbed through pores in the cell wall. Where, as in some parasitic forms, the cell wall is thin, the requisite rigidity of form is supplied by an internal skeletal rod-like body termed the **axostyle.**

Co-ordination between locomotor organs, and the connection of these with the all-controlling nucleus, is attained by a complex apparatus comparable in some respects to a nervous system and hence referred to as the **neuromotor apparatus.**

The flagella, as a rule, arise together at the anterior end of the animal from a stainable granule termed the **blepharoplast,** which again is attached by a stainable thread, the **rhizoplast,** to a body on the further side of the nucleus known as the **parabasal** body. As to the exact function of this body, some controversy exists, but the more prevalent view sees in it a sort of power house for the locomotor organelles. In blood-frequenting Mastigophora (Fig. 2), this parabasal body is represented possibly by the so-called kinetonucleus which lies between nucleus and blepharoplast.

The great contrast that exists between the appearance of a typical Mastigophoran and a typical Sarcodinan does not imply that a deep gulf of morphological dissimilarity divides the two groups. As a matter of fact, many Mastigophora pass through an amœboid stage in their life-cycle, and the sarcodine form *Mastigoamœba* possesses a typical flagellum, yet moves and feeds in typical amœboid fashion. There can be little doubt that the two classes have diverged from a common ancestral stock.

The **Sporozoa** is a collection of forms living always inside other animals and varying from one another very much in structure, life-cycle, habits, and so forth, but linked together by the character of *spore formation*, that is to say, the power of producing numerous resistant seed-like bodies which can

resist environmental conditions outside the host until an appropriate host can be entered again (Fig. 3).

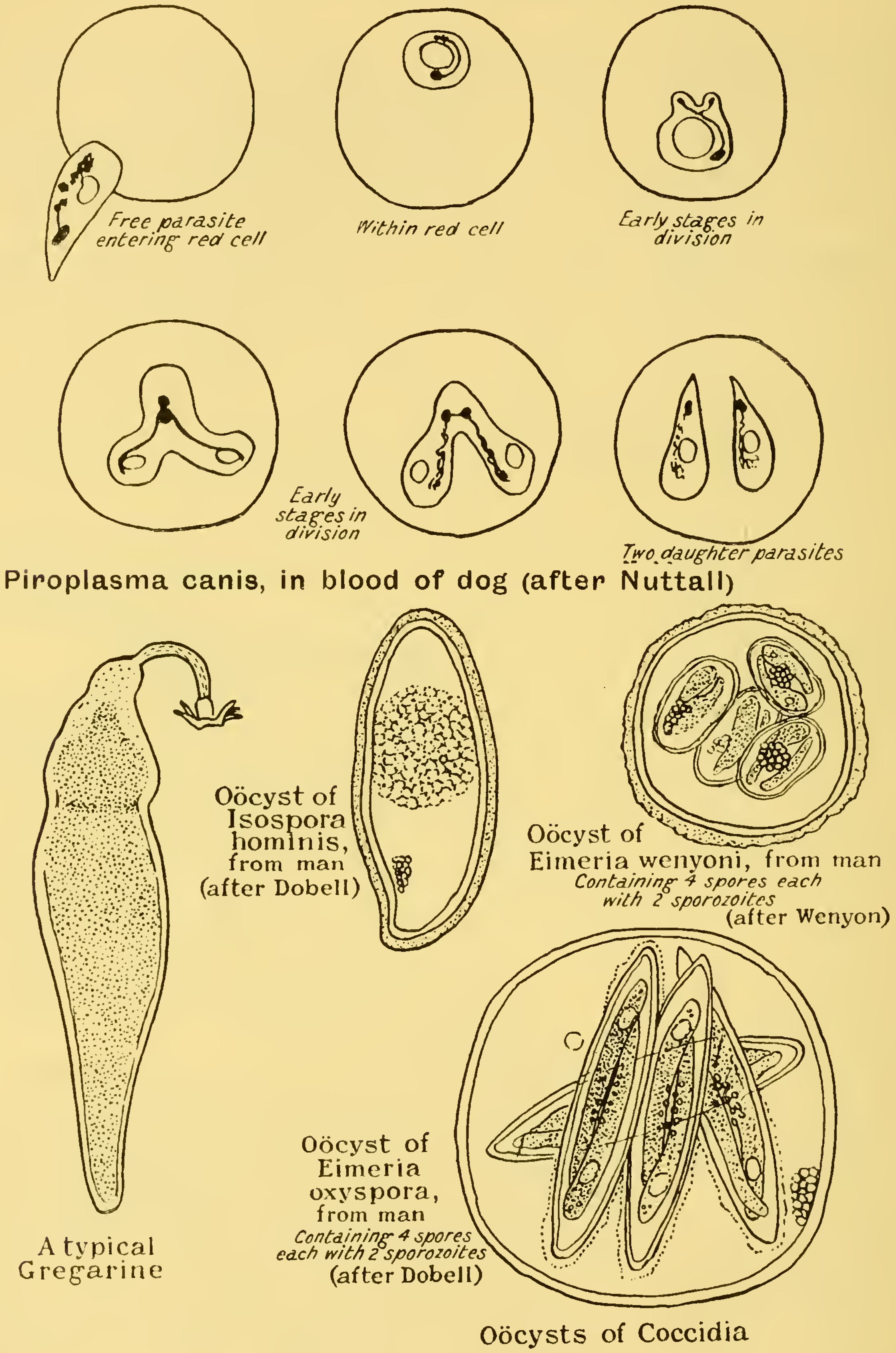



Fig. 3.—Types of Sporozoa.

Spore formation, however, is not a sufficient basis for the association in one class of such a heterogeneous crowd of creatures ; it is not different in principle from cyst formation, and cyst formation occurs in widely divergent Protista ;

further, many so-called Sporozoa do not produce spores at all. It seems certain that the two main subdivisions, the Telosporidia and the Neosporidia, are quite distinct in origin; the former group show affinities with Mastigophora; the latter group possess features which suggest descent from Sarcodina.

Typically, there are two phases in the Sporozoan life-cycle:—

(1) A **trophic phase,** a nutriment absorbing stage, which may be amœboid or gregarinoid (worm-like), may be lodged within a host cell or between host cells, or may be free within some host cavity. Nutrition is always by osmosis of the host fluids through the thin cell wall of the parasite. This stage may multiply and produce other trophic individuals, which are usually referred to as **trophozoites.** Such reproduction is non-sexual and is termed the **schizogonous** method of reproduction.

(2) A **sporont** phase, which is a non-feeding stage. This stage is characterised by the breaking up of the individuals into **gametes** or reproductive cells. These fuse in pairs to form a zygote, as it is termed. The zygote then proceeds to form around itself a thick cell wall, and may now be termed a spore, or else its body substance becomes divided into portions, each of which forms a cell wall and becomes a spore. Within each spore the protoplasm divides into a number of so-called **sporozoites,** which are potentially infective feeding individuals. The division of a zygote into spores is termed **sporogonous reproduction.**

The Telosporidia show a distinct alternation of trophic and sporont phases in their life-cycle. The Neosporidia show an overlapping of the two phases, an individual being capable of undergoing spore formation whilst still in the trophic stage.

The last class of Protozoa, the **Infusoria** or **Ciliata,** is a well-defined and compact group whose members can be considered, in view of the great complexity of their cell organs, as the highest of the Protista.

The primitive type of Ciliate is probably the oval gooseberry-shaped type of creature with terminal mouth and an even coating of fine hair-like motor organelles termed **cilia,** whose co-ordinated movements enable the creature to move with comparative rapidity. In other forms, however, the mouth has shifted to the side of the body, midway towards the posterior pole, and the rows of cilia run obliquely around the body; again, in creeping forms, the body has become shaped like an inverted pie-dish, the cilia being stiff, large, and restricted to the flattened ventral surface. Other forms, again, are sedentary and stalked, and the cilia arranged in circles around the free

end. Nearly all are holozoic and a definite mouth is usually present (Fig. 4).

This is an aperture leading into an œsophagus which ends blindly in the cytoplasm. In the great majority of Ciliata the mouth aperture is permanently open and the area around it contains a spiral zone of modified cilia which induce particles to enter. Further progress down the œsophagus is effected by the influence of one or more undulating membranes which

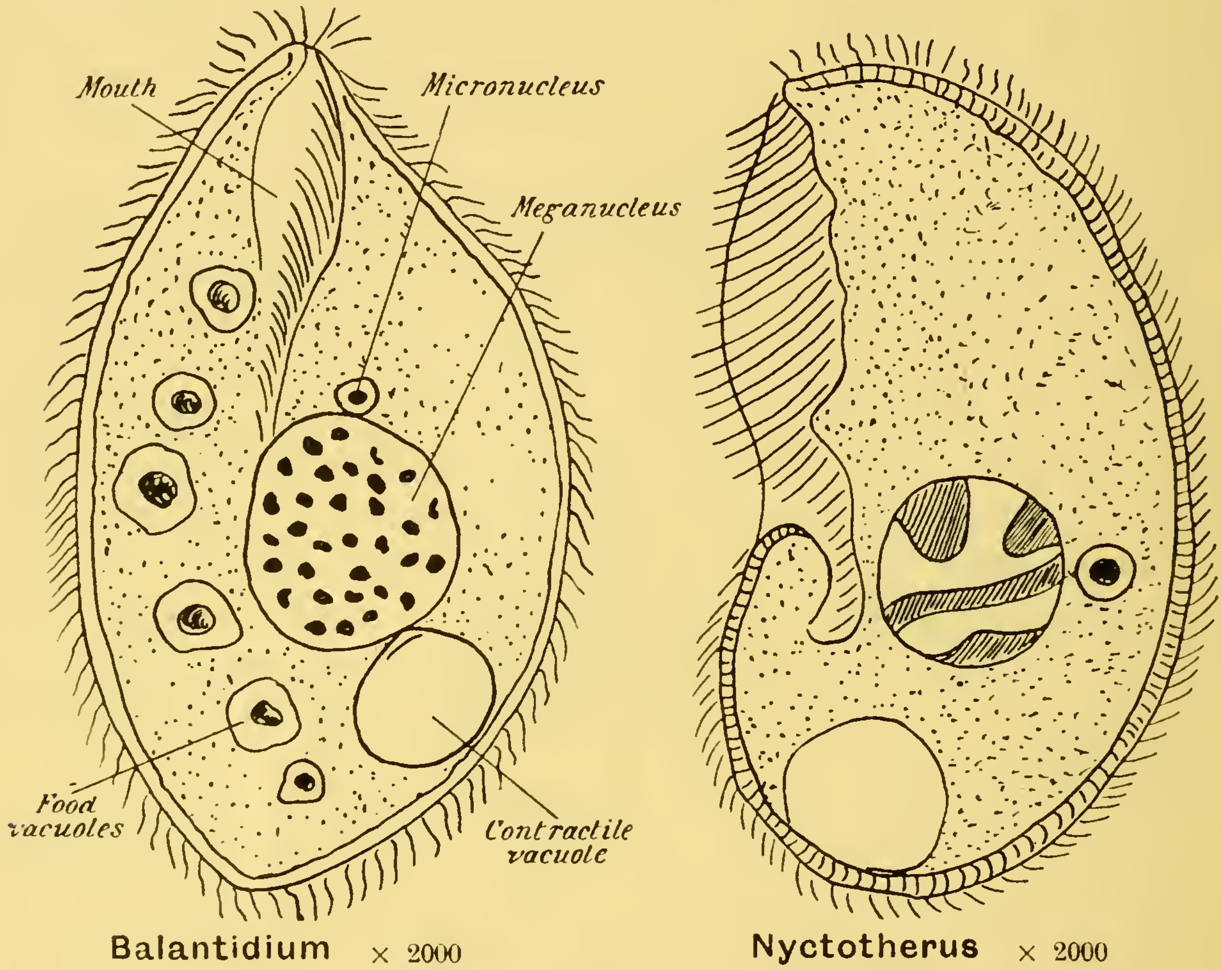



FIG. 4.—Enteric Infusoria. (After Dobell.)

represent fused rows of cilia ; in certain forms, however, which inhabit the stomach of ruminant mammals, the mouth can be closed or opened by a series of rods in the œsophageal wall.

Food debris is evacuated through a pore, the so-called **cytopyge,** in the cuticle, but this may only be visible at the moment of evacuation.

Two nuclei are typically present. There is a large deeply staining body, the **macronucleus,** controlling the general metabolic activities, and a **micronucleus,** very much smaller in size, which is a controlling factor in the sexual phase of reproduction.

# CHAPTER II

## PROTOZOA : The Distribution

Protozoa are widely distributed both geographically and environmentally. The seas and fresh waters of all countries swarm with an almost infinite variety of unicellular life ; the surface pools of thawing glaciers and icebergs, the evanescent puddles produced by the rare and heavy rainstorms upon the dusty face of the desert, alike are populated with Protozoa ; there is scarcely any form of soil which will not, when moist, give evidence of the presence of these creatures ; the very rocks of the earth's crust are, in some localities, cemented aggregations of fossilised Protozoa ; there is probably no animal which does not act as involuntary host to myriads of them.

Nor is it necessarily the case that geographically isolated areas possess physiologically isolated protozoan faunas. World-wide occurrence of a particular genus or species is a phenomenon common in the distribution of this group. The protozoan species of a Lancashire pond will vary little, if at all, from the fauna of a pond in Minnesota or elsewhere.

Now such cosmopolitan distribution is attainable by an animal or plant only if, in the first place, its physiological mechanism be sufficiently plastic to permit adjustment to a wide range of environmental fluctuations—different degrees of osmotic tension, of temperature, of food-stuff distribution, and so on ; and, in the second place, if it possesses exceptional opportunities for migration.

Among Protozoa, such conditions are fulfilled particularly by very many of that vast assemblage of forms whose normal habitat is fresh water, and it is precisely to this group that the most cosmopolitan Protozoa belong.

It must be noted, of course, that however adaptable a race of Protozoa may be to changes of its environment, it will not readily adapt itself to changes which are outside the normal experience of the race. Temperatures above 40° C., or sudden transitions, for example, to distilled water or to chemical solutions, are usually fatal. It would be a matter of great surprise if they were not. If, however, such transitions be

allowed to occur gradually, the race can be educated to withstand conditions extremely different from those to which it normally is subjected. Fresh-water Protozoa have been successfully acclimatised to saline water, to alcohol, even to solutions of corrosive sublimate.

Physiological plasticity is a *sine qua non* to the existence of forms whose normal habitat is fresh water sufficiently shallow to be influenced by meteorological changes; pools and ponds and puddles, in fact, where temperature, osmotic tension, and food-stuff distribution are fluctuating factors of existence. Such forms possess two physiological weapons with which to meet the menace of fluctuating environment; defence and attack are personified by those antithetic phenomena—**encystment** and **rapidity of reproduction**—representing, as it were, the trough and the crest of the metabolic wave.

Should environmental conditions fluctuate, so to speak, beyond the limits of endurance, the organism encysts; that is to say, its activity ceases, its shape becomes spherical, and, in accordance with the laws governing surface tension, it loses much of its tissue fluid so that its tissues shrink, increase in viscosity and opacity, and there occurs a peripheral coagulation of protoplasm to form a protective membrane which may be further strengthened by a carbohydrate secretion.

Such a cyst is extremely minute, and it is extremely resistant, easily withstanding comparatively low and high temperatures.

It adheres readily to particles of mud or of vegetation, and is thus easily distributed by birds and amphibia, fishes and water insects, or by the wind. However dry the external environment may be, the cyst wall is sufficient to prevent evaporation of the precious tissue fluid. It can endure, for years, conditions which would immediately kill the unencysted form, yet upon the return of favourable conditions of moisture and temperature, however brief their duration, the cyst will liberate the active organism which can then proceed to feed, to grow, and to multiply, until the gradual or sudden onset of unfavourable conditions forces it to encyst again.

Encystment, however, as indicated previously, is not necessarily a passive adaptation to adverse conditions of life. It may be a normal incident in the life-cycle of the animal. Particularly is this the case where the life-cycle shows an alternation between sexual and non-sexual phases of reproduction.

The phenomenon is not confined to fresh-water forms of Protozoa. It is almost universal among internally parasitic

forms. Such forms, however, are limited in distribution owing to their dependence upon the distribution of the host. If the host, however, be a type such as *Homo sapiens*, which is cosmopolitan in distribution, there is much probability that the internal protozoan fauna will be specifically similar, whatever the geographical distribution. More knowledge concerning this question is required. Among marine forms, on the other hand, the phenomenon of encystment is not commonly met with. With them conditions of life seem to be more equable; benthic or bottom-dwelling forms are not subject to very great fluctuations of temperature; pelagic or surface-dwelling forms can adjust themselves to environmental fluctuations by vertical ascents and descents. At any rate, apart from a few world-wide forms, *Noctiluca*, for example, cosmopolitanism has not been demonstrated as a common phenomenon among marine Protozoa. Possibly further investigations will contradict this.

So far as present knowledge goes, however, we can distinguish between cold water and warm water forms, between Indian Ocean and Atlantic forms.

We may conveniently regard Protozoa, from the point of view of environmental distribution, as falling into four ecological groups :—

(*a*) *Limnobiotic* or fresh-water forms.
(*b*) *Halobiotic* or marine forms.
(c) *Phytobiotic* forms, associated intimately with plants.
(*d*) *Zoobiotic* forms, associated intimately with animals.

*Saprobiotic* forms, associated with decomposing organic matter, and *geobiotic* forms or terrestrial forms, may be regarded as sub-groups of (*a*).

**Limnobiotic Protozoa.**—The term "fresh-water Protozoa" is somewhat of a misnomer.

Fresh water, in the usual sense of the term, as typified by running water, springs, town water supplies, is singularly free from Protozoa, owing to its freedom from bacterial life and from suspended organic matter. On the other hand, stagnant water foul with organic decay, or sewage or liquid manure, affords optimum conditions to Protozoa. In such a medium they abound. Many forms are omnivorous, absorbing any kind of organic matter which is within their powers of prehension. Others are gourmets, selecting with epicurean caprice only Diatoms, Oscillariæ, or Bacteria.

From bacteriophagous forms are derivable the great majority

of so-called terrestrial or moist earth Protozoa, to be discussed more fully in a later chapter.

From omnivorous forms, very many Protozoa that only frequent decaying organic matter are possibly derived.

The true saprobiote, however, is an osmotic feeder, to whom organic compounds in solution are necessary, and this type has possibly descended from holophytic forms. Such out and out saprobiotes as *Chilomonas* and *Polytoma* have many similar holophytic relatives. Very many green forms frequent foul fluids rich in the dissolved products of organic disintegration and supplement photosynthetic and osmotic methods of feeding by actual ingestion of Bacteria and small Protozoa through a sort of mouth. Forms, almost identical morphologically with the green ones, except for the absence of chromatophores, live side by side with them, and it cannot be supposed that they have lost that osmotic method of feeding so characteristic of green types.

In a watery infusion of chopped hay, straw, or moss, after the lapse of a few hours, various types of Protozoa appear in waves of succession. Thus, the Bacteria are followed by bacterial eaters, such as the mastigophoran genera *Monas*, *Oikomonas*, and *Bodo* ; the ciliate genera *Colpoda*, *Colpodium*, *Chilodon*, *Paramœcium*, and *Vorticella* ; and such sarcodine genera as *Vahlkampfia* and *Amœba*. These forms gradually become overwhelmed and replaced by forms which feed partly upon Bacteria, partly upon Ciliata, such forms, for example, as *Stylonychia*, *Euplotes*, *Gastrostyla* ; and, finally, by forms which feed entirely upon Ciliata, *Euchelys* and *Coleps*, for example. After decomposition has ceased there appear the Green Algæ and Flagellata, accompanied by Rotifera, Nematode worms, Gastrotricha, fresh-water Crustacea, and so forth.

Such a succession of forms is obtainable, it may be pointed out, even where the infusion and containing vessels have been sterilised by methods efficient enough to destroy any pre-existing cysts of Bacteria or Protozoa. The various components of the succeeding protozoan fauna must be derived, therefore, from air-borne cysts.

In very stagnant accumulations of water, where dissolved oxygen is scarce and dissolved sulphuretted hydrogen is plentiful, there occurs a protozoan fauna which is able to live almost anaerobically, approximating in biological environment to the commensal and parasitic forms of an animal's alimentary canal. These alimentary canal forms may possibly have been recruited from the forms which live in stagnant infusions.

**Phytobiotic Protozoa.**—These forms are few in number, a fact correlated perhaps with the apparent absence of cellulose-splitting ferments in the animal body. Certain amœboid forms have been noted within holophytic Mastigophora, particularly in *Volvox* and *Hœmatococcus*, and a form *Vampyrella* occurs within the cells of Green Algæ. Such forms are cell robbers. The Myxomycete, *Plasmodiophora*, is a parasite of higher plants. Certain flagellate forms also have been discovered in the juices of euphorbiaceous plants.

**Zoobiotic Forms.**—These forms, on the other hand, are extremely numerous. It is doubtful, in fact, whether any metazoan animal is entirely free from associated Protozoa. Scarcely any group of Protozoa, except a few rigidly specialised orders such as Radiolaria and Foraminifera, is without zoobiotic members.

To generalise zoobiotic Protozoa as parasites would not be correct. A very large number undoubtedly are parasitic. Many forms are of proved pathogenicity. Other zoophilous forms, however, may be possibly of physiological value, rather than a detriment, to the host organism.

Zoobiotic forms may conveniently be split into two divisions :—

(*a*) **Ectozoic** forms, which frequent the external body surface or involutions of the body surface such as mouth, gill chamber, cloaca of the host animal.

(*b*) **Endozoic** forms, which live within the host animal.

Ectozoic forms may be entirely harmless to the host animal.

The gills of Crustacea are sometimes infested with sedentary Ciliata, which merely seek a coign of vantage from which to secure their minute victims. Many Hydroids and Sponges are infested with similar forms and with creeping Sarcodina and Ciliata. The Green Hydra (*Hydra viridis*), for example, is commonly infected with hypotrichous Ciliata.

Many ectozoic forms, however, feed on their substratum and so seriously damage their host.

*Costia necatrix*, for example, is a flagellate Protozoan which attaches itself to the skin of fresh-water fishes and damages the epidermis, so paving the way for bacterial infection and consequent suppuration and ulceration. The Ciliate *Ichthyophthirius multiilis* has similar habits.

Endozoic Protozoa exploit almost every type of host organ : skin, peripheral and central nervous system, blood, gut, reproductive organs, muscles, even bony and cartilaginous skeletons. The majority, however, can be divided into connective tissue

forms, *enteric* or alimentary canal forms, and *hæmatophilous* or blood-frequenting forms.

In each habitat there occur forms which penetrate into the actual tissue cells, and forms which are content to remain between the cells.

Connective tissue forms belong chiefly to the Neosporidia group of Sporozoa, which although in no case include parasites serious to man, include certain forms of great pathogenic effect upon fish and insects.

Of the three groups comprising the Neosporidia :—

(1) The **Myxosporidia** are chiefly parasites of fishes, and have a comparatively simple life-cycle, without involving any intermediate host ; they occur in the gall bladder, gills, kidney, urinary bladder, muscles, connective tissue, spleen, ovary.

A fish becomes infected by swallowing spores. Each spore is bivalved and has a thick wall or *sporocyst*, within which occur two so-called polar capsules containing each a coiled filament and a mass of protoplasm containing two nuclei. When the spore is acted upon by the conditions in the fish gut, the filaments are protruded and anchor the spore to the intestinal wall ; the mass of protoplasm creeps out as an amœba-like organism, penetrates the gut wall, and is carried by the blood stream to the particular habitat characteristic of the species.

(2) The **Microsporidia** are principally parasites of insects and include particularly *Nosema apis*, the organism of Nosematosis of bees, *Nosema bombycis* of the silkworm disease *pébrine*, and *Thélohania contejeani* of crayfish disease. The spore of these forms possesses only one polar capsule. With *Nosema apis* the amœbula, which emerges from the spore, spends its life-cycle within one of the epithelial cells which line the intestinal tract of the bee. These cells become filled with spores, the majority of which pass out with the fæces to infect other hosts.

In the case of *Nosema bombycis*, however, the amœbulæ invade other organs of the body, and spores even occur in the ovary and within the eggs of the moth, so that the disease is transmitted to the newly hatched caterpillars.

(3) The **Sarcosporidia** occur as rod-like masses of spores between the fibres of the striped muscles of mammals, particularly the muscles of the œsophagus and diaphragm. These so-called Miesche's tubes are large enough to be visible to the naked eye. The life-cycle is imperfectly known, but the spores are said to be motile and, if introduced into the intestinal

tract of a fresh host, to penetrate the gut wall and make their way to the muscles (Fig. 5).

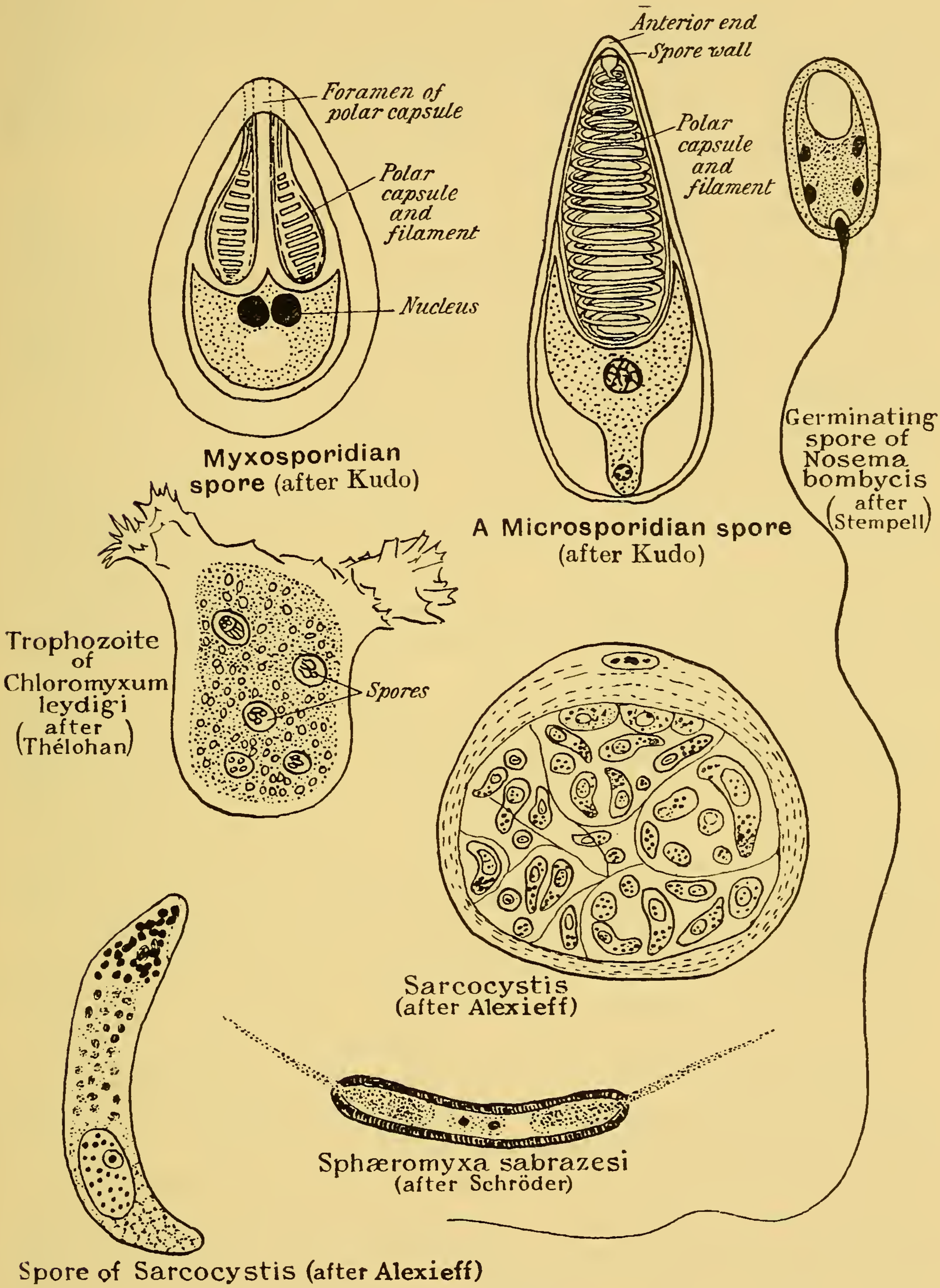



Fig. 5.—Types of Neosporidia.

Enteric and hæmatophilous Protozoa will be discussed in succeeding chapters.

Zoobiotic Protozoa may injure the host in various ways.

The damage may be mechanical, brought about by pressure or movement of the Protozoan between the cells of the host tissue ; or the intruder may clog up a minute duct or blood-vessel ; or it may affect the host animal by absorbing circulating fluids which should normally nourish the host itself. Again, the host may suffer injury owing to actual tissue destruction by the Protozoan, or may suffer from the toxicity of the excretions from it.

Many blood parasites have a particularly injurious effect upon the red blood corpuscles. In such diseases as malaria, babesiosis, trypanosomiasis, the red blood corpuscles are destroyed in great numbers, possibly by a hæmolytic ferment excreted from the parasite. Injury to the host from blood-frequenting Protozoa results from such diminution of red blood corpuscles rather than from loss of nutrition fluid.

The possibility of Protozoa being able to excrete water-soluble toxic substances seems to be generally accepted, although few facts are available. The dying down of cultures of Protozoa, despite abundant oxygen and food, is probably due to the presence of such toxins ; the febrile symptoms occasioned in the host by many blood-frequenting Protozoa probably result also from excreted toxins.

It may be added that Protozoa themselves are not exempted from the inconvenience of unbidden guests. Such invaders may be predatory rather than parasitic, as they directly invade the protozoan victim, but others are taken in with food and in their tolerance to the host digestive reactions behave like true internal parasites. The majority of these parasites are fungi, belonging to the families *Saprolegniaceæ* and *Chytridiaceæ*.

Members of the latter family would seem to be the causative agents of the so-called " giant nuclear condition " of amœbid and of thecamœbid forms described by many authorities.

*Chytridiaceæ*, also, are very prevalent as parasites of the *Euglena* and *Chlamydomonas* groups of Mastigophora. Ciliates seem particularly liable to bacterial infection. Thus, in *Paramœcium*, *Stylonychia*, and some other forms, bacteria may occur in chains and in clumps in the plasma, and destruction of the mega-and micro-nuclei may occur. Even Nematode worms have been observed in the giant Ciliate *Pycnothrix monocystoides*, which occurs in the gut of the coney (*Hyrax capensis*).

The genus *Stentor* is also liable to infection from small Mastigophora whose presence seems to reduce the host's vitality considerably and may even bring about disintegration.

# CHAPTER III

## PROTOZOA : Enteric Forms

An enormous number of protozoan species live as normal habitants of the alimentary canal of some other animal. There is probably no animal in possession of a well-marked alimentary tract which is entirely free from such organisms.

The conditions within an alimentary canal are almost ideal for forms which can withstand the paucity of oxygen and the action of digestive juices. There is sufficiency of moisture and warmth and sufficiency of food, whether in the form of bacteria, of nutritive juices, or of food débris such as starch grains or cellulose.

A vast crowd of Protozoa have adapted themselves to this mode of life, and their derivation from saprobiotic forms would seem evident from various facts ; from the occurrence, for example, of both saprobiotic and enteric species of the genus *Bodo*, *Hexamitus*, and other genera ; and from the readiness with which some intestinal flagellates can be cultivated as saprobiotes.

Gut-living Protozoa are drawn from all groups, but Ciliata and Mastigophora predominate naturally, since they are the most likely types to gain admittance to the alimentary tract, and since their motor apparatus is well adapted to the great energy expenditure required for locomotion in the viscous fluids of an alimentary canal.

It would be far from correct to describe gut Protozoa as generally parasitic. The great majority are probably harmless scavengers, subsisting upon food residues which have withstood the disintegrating action of the host's digestive ferments. Attempts have, in fact, been made to show that enteric Protozoa in host animals whose alimentary canal contains much cellulose, may be of considerable physiological value, owing to their ability to decompose this carbohydrate substance. It has been asserted that such animals as herbivorous mammals and wood-feeding insects could not carry on without this internal fauna. There is no doubt, however, that many cases occur where gut-frequenting Protozoa are actually inimical to

the host, and possibly many more such cases remain to be elucidated.

Protozoa which have adopted the enteric mode of life show certain features in common which, occurring as they do in forms belonging to different taxonomic groups, can be regarded as adaptations to this mode of life.

Movement in a viscous medium requires, for example, a locomotor apparatus of considerably greater power than is required by forms which live in fluids of comparatively low density.

Flagella, for example, tend to be more numerous, to be longer, to become fused into undulating membranes, and there is often, in enteric Flagellata, an extranuclear neuromotor apparatus occurring usually as a so-called "parabasal body" attached laterally to the blepharoplast at the base of the flagellum.

In enteric Ciliata the cilia tend to be powerful and numerous.

Enteric Sarcodina have large, powerful pseudopodia which propel the animal in one definite direction.

Another feature displayed by probably all enteric Protozoa is the phenomenon of encystment. Speaking generally, the life-cycle in these forms consists of two alternating periods :—

(*a*) A period of comparative freedom and mobility, during which the organism grows and reproduces ; and

(*b*) A period of rest, during which metabolism is at a low ebb, and which is spent outside the host, protected from a fluctuating environment by a cyst wall. The encysted stage is usually the infective one, and the organism will emerge from it only in response to stimuli exerted by the alimentary juices of the appropriate host.

Infection of the host in the case of enteric Protozoa is invariably brought about by the swallowing of an encysted stage ; no intermediate host seems ever to be interposed in the life-cycle of an enteric Protozoan, although undoubtedly such animals as flies, in whose gut the cysts do not hatch, may serve to distribute the enteric protozoan parasites of higher animals.

Cysts of enteric Protozoa seem to be less resistant to desiccation than are those of free-living forms. Moisture would seem to be a necessary adjunct to the success of their dissemination.

Enteric Protozoa belong chiefly to the two classes *Infusoria* and *Mastigophora*. There are, however, a considerable number of enteric amœbæ and a large number of enteric Sporozoa belonging to the *Gregarinida* and *Coccidiidea*.

**Enteric Amœbæ.**—Enteric amœbæ have been recorded from many different types of animals; from animals so diverse even as man, mouse, cockroach, and oyster; undoubtedly many more await discovery.

There was formerly very great confusion concerning the homologies of these amœbæ; material was insufficient, or it was stale, or it was examined by methods which were far from efficient.

The widespread occurrence of chronic diarrhœa and dysenteries of various kinds existing among troops during the Great War, however, afforded unusual opportunities for the study of the internal amœbæ of man, and these amœbæ are now comparatively well known. It would seem, in the light of present knowledge, that there occur in man no fewer than four genera, comprising six distinct species; these genera are *Entamœba*, *Endolimax*, *Iodamœba*, and *Dientamœba*. All these amœbæ are small in size as compared with free living forms, and they lack contractile vacuoles. They are separable chiefly upon structural differences of nuclei and cysts.

Of these forms, much the most important from an economic standpoint is the genus *Entamœba*. Strictly speaking, the generic name of *Endamœba*, suggested by Leidy in 1879, should have priority of application to this genus, but as Leidy's term was given to the intestinal amœba of the cockroach, and as it is doubtful whether this cockroach parasite is cogeneric with the three principal amœbæ of man, it has been suggested by Dobell, upon whose monograph much of this account is based, that the term *Entamœba* applied originally by Casagrandi and Barbagallo to the amœbæ of man, in ignorance of Leidy's work, should be preferred.

Three species of *Entamœba* are known at present.

**Entamœba histolytica** inhabits the large intestine of man and is probably world wide in its distribution. It can be transmitted experimentally to Carnivora and possibly to Rodentia, but there is no evidence that it occurs normally in any animal except man. It is comparatively large for an enteric form, averaging about 25 microns when observed fresh from the host; it is very active, flowing along in a slug-like manner, and fairly rapidly, by the aid of a single, anteriorly-directed pseudopodium, and showing little distinction between ectoplasm and endoplasm; but if it has been outside the host for some time, it is sluggish and throws out clear blade-like pseudopodia composed of ectoplasm only. The cytoplasm may be clear and free from foreign bodies, owing to the fact that this species feeds rather

by absorption than by actual ingestion of food particles, but very frequently the cytoplasm contains tissue cells and red blood corpuscles ; the presence of the latter may be taken as diagnostic of this species. It never seems to feed on bacteria. The nucleus is characteristic, being spherical, vesicular, and provided with a layer of darkly staining peripheral granules, which, in stained preparations, produce a ring-like appearance. In the centre of the nucleus is a karyosome, surrounded in stained preparations by a halo-like region produced by an area of non-stainable substance. In good preparations there is an absence of chromatin between the karyosome and the edge of the nucleus (Fig. 6).

*Entamœba histolytica* is primarily an inhabitant of the colon, and produces extensive ulceration of the colon wall ; it is able to bore its way into the walls of the colon, possibly by the aid of a cytolytic ferment, and may even get into capillary vessels and be carried to the liver, brain, or lungs, there to produce abscesses. Normally it reproduces by simple division into two. At times, many of the amœbæ pass back into the intestinal lumen, and divide into four or more daughter amœbæ, which are, of course, very small. These so-called " precystic forms " generally encyst and are passed out of the host to the exterior.

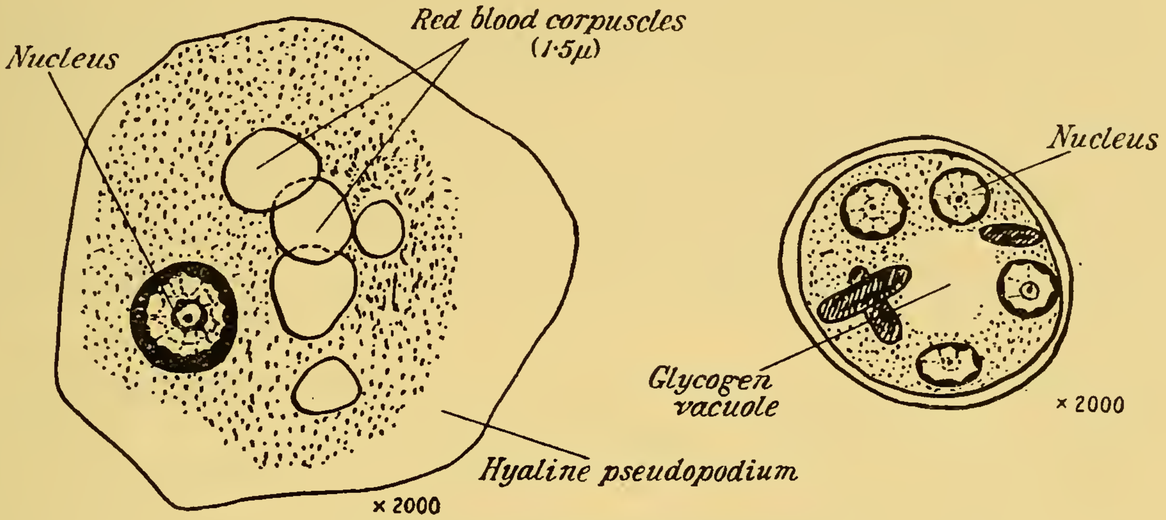
The ripe cyst has four nuclei and contains also peculiar shining masses of stainable substance termed **chromatoid bodies.** Such cysts can retain their vitality in water or in moist fæces probably for weeks, but are very susceptible to dryness or to increase of temperature.

Man is probably infected by contaminated food or water. The cysts would appear to pass through the human stomach unaltered, but once past the stomach they hatch and liberate each a quadrinucleate amœba, which subsequently divides into four small uninucleate amœbæ.

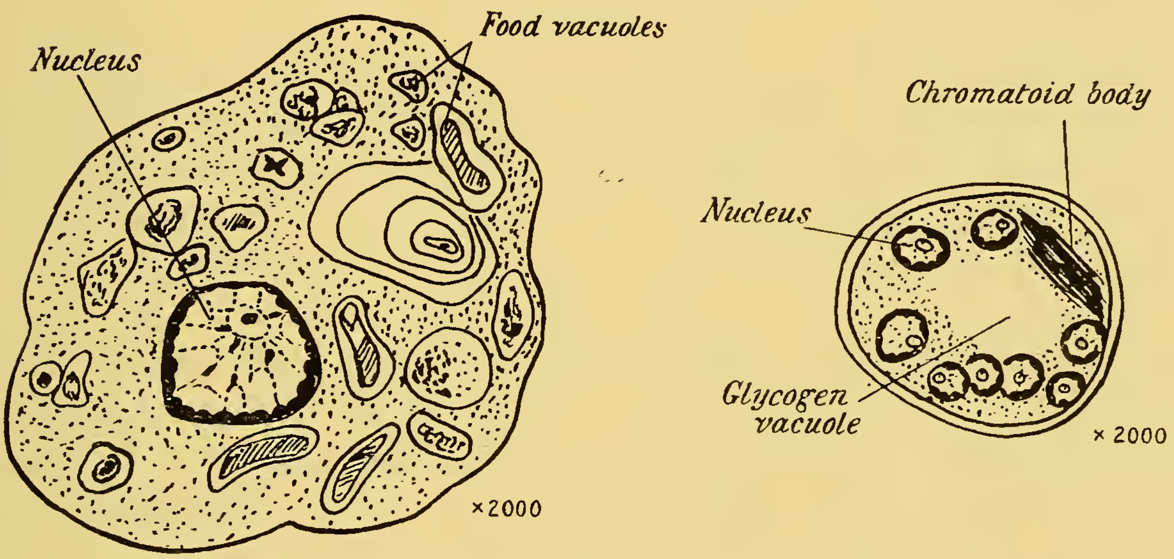
It is possible that many infected hosts act as " carriers " ; in such an individual the intestinal tissues regenerate as fast as they are destroyed, and no dysenteric symptoms develop ; such individuals can be distinguished from uninfected individuals only by the presence of the cysts in their fæces. Carriers are, of course, a permanent menace to the health of the community.

If, however, in a host individual the rate of tissue regeneration falls behind the rate of tissue destruction by the parasite, then disharmony will be brought about between host and parasite, and both will become affected pathologically. The host will develop typical Amœbic Dysentery, accompanied by

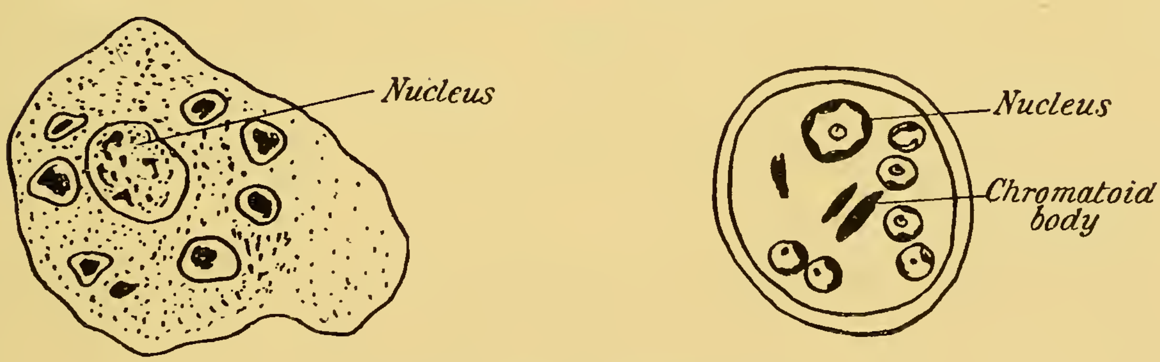
great ulceration of the intestinal epithelium, and sometimes by secondary complications such as liver abscesses or even joint rheumatism and skin affections.




Entamœba Histolytica and Cyst.




Entamœba Coli and Cyst.




Entamœba Muris and Cyst.

Fig. 6.—Enteric Amœbæ. (After Dobell and Wenyon.)

Among the amœbæ, great mortality and wastage will then occur, since large numbers are expelled from their habitat before they have been able to encyst, by the diarrhœic symptoms of the host.

Dysentery, therefore, would seem to be an abnormal result of the presence of *Amœba histolytica*, for, if a normal result, the parasite would tend towards extermination. At the same time, it is doubtful whether a host individual can always remain a passive carrier ; he may remain so for years, and then suddenly develop an acute attack of dysentery or a liver abscess. Amœbic dysentery and hepatic abscesses are commoner in the tropics, but it must be noted that they can occur in temperate countries. According to Dobell, probably 7-10 per cent. of the population of the British Isles is infected with *Entamœba histolytica*.

The treatment of amœbic dysentery is too purely a medical question to be discussed here, but reference may be made to the specific action of the alkaloid emetine, which has been found to rid infected individuals from the parasites, although it does not seem to be particularly toxic to them ; possibly it reacts through the host.

**Entamœba coli** is another widely distributed inhabitant of the human colon. The average percentage of the population of England, France, and United States infected with this amœba would appear to be about 20, as against 9 for *E. histolytica*.

*Entamœba coli* is a large organism, similar in size to *Entamœba histolytica*, but less active and without the habit of suddenly protruding clear pseudopodia. The nucleus is very conspicuous, even in the living animal, as an eccentrically placed beaded ring. The cytoplasm is coarser than in *E. histolytica*, and may contain all manner of food derived from the colon, such as bacteria, vegetable débris, cysts of other Protozoa, and so on, but never, according to Dobell, does it contain red blood corpuscles. The organism, in fact, is probably a harmless commensal. Cyst formation takes place very much as in the case of *E. histolytica*, but the ripe cysts differ in containing eight nuclei (Fig. 6).

**Entamœba gingivalis** is a smaller amœba than the two already described ; it is a smaller and more active edition of *Entamœba coli*, and occurs not in the gut but on the teeth, being commonly found in cases of oral suppuration. It has been suspected of being a contributory factor to the occurrence of pyorrhea.

**Endolimax** is a genus containing only one known species, namely, *E. nana*. It is probably the commonest amœba of the human gut, and is distinguished from the genus *Entamœba* by its smaller size, by the absence of a karyosome

in the nucleus, and by certain peculiarities of cyst formation. It is believed to be harmless. The cyst has four nuclei. *Endolimax* was found to be the commonest amœba infecting American soldiers in 1918, the percentage of infection being 28.

**Iodoamœba** has one species, namely, *I. bütschlii*; it was described by Prowazek in 1912 as *E. bütschlii.* The cysts, which have a glycogen body within them, were first described by Wenyon in 1915 in soldiers from Gallipoli, under the term of "iodine cysts," owing to the glycogen content of the cyst being stainable dark red with iodine. This amœba may possibly be merely a large race of *E. nana.*

**Dientamœba** comprises the single species *D. fargilis.* It is a small gut amœba, possessing two nuclei; the cysts are not known. It is believed to be harmless.

Kofoid has distinguished from *E. coli* an amœba which he claims has been previously confused with it. This amœba, which he has termed *Councilmania Lafleuri*, agrees with *E. coli* in size and in the possession of an eight-nucleated cyst, but it is more active, readily ingests red blood corpuscles, and has a cyst with a thicker cell wall. As regards the intestinal amœbæ of animals other than man, very little information exists. A form, *Entamœba meleagridis*, living in the cæca of turkeys, has been associated with a hepatic disease of young turkeys in the United States, called "blackhead" owing to the dark colour assumed by the wattles.

Certain subcutaneous tumours of horses, referred to generally as *botryomycosis*, have, on very doubtful evidence, been regarded as caused by an entamœba, namely, *Amœba letullei.*

It must be emphasised that the differential diagnosis of enteric amœbæ, particularly of those living in man, is a matter of very great difficulty, and a task to be attempted only by a fully trained and experienced protozoologist. Not only are the various genera so variable in size and in cytoplasmic structure as to be readily confused, but their cysts, whose exact identification is a matter of great importance, may have the same optic properties as quite different organisms, such as cysts of the flagellate *Chilomastix*, yeasts, degenerate leucocytes, and so on. In carriers and in chronic cases, diagnosis of amœbiasis depends largely upon identification of the cysts, since the active amœboid stages rarely occur in fully formed stools.

**The Enteric Mastigophora.**—The great majority of enteric flagellates belong to that order of Mastigophora known as the *Polymastigina* owing to the presence of numerous flagella. All

the members of this order, in fact, are in some way or other zoobiotic.

They are comparatively small forms provided with two to six flagella, of which at least one trails posteriorly and may be attached to the body so as to form an undulatory membrane (Fig. 7).

It is in these polymastigine forms that the neuromotor apparatus, referred to previously, is met with in its most highly developed form. The plurality of flagella, the complex neuromotor apparatus, and the presence frequently in these forms of something in the nature of an internal skeleton composed of one or more rods or *axostyles*, may possibly be points correlated with life in a medium somewhat more viscous than that of stagnant water.

Almost all the Polymastigina are holozoic, feeding upon microscopic organisms and detritus; many have a definite mouth leading into a short funnel-like gullet. They have generally the power of encysting, and such cysts are probably the chief means of distribution of host infection.

There is great variety of structure, ranging from simple organisms like *Prowazekia* in the gut of lizards, provided with a long anterior flagellum and a long trailing one, to forms such as the *Calonymphidæ* in the gut of termites, which have many nuclei, many blepharoplasts, and numerous axial rods bound into a central bundle; they have also many parabasal apparati and numerous flagella, arising in bundles of four from each blepharoplast.

Of the very many enteric Polymastigina, the following forms may be noted:—

**Trichomonas** is a genus recorded from many host animals. It has been recorded from the mouth, gut, vagina of man, the gut of the mouse, guinea-pig, amphibian, lizard, pigeon, snails, leeches, insects, and so on, and from the stomach of ruminants. Probably the forms thus recorded are specifically distinct, but if so, their morphological differences are very slight.

Usually they are minute forms and usually oval in shape, though capable of a certain amount of change of shape. There are four flagella, which comprise three anteriorly directed, and one posteriorly directed and fused to the body to form an undulatory membrane (the *Trichomonas form*), or free from the body (the *Trichomastix form*). The undulatory membrane, if present, winds slightly round the body, so that the animal rotates as it swims. There is an internal axial rod which projects so that the animal shows a posterior spike. There is

a minute mouth, anterior in position and ventral to the undulatory membrane. The organism feeds on small bacteria.

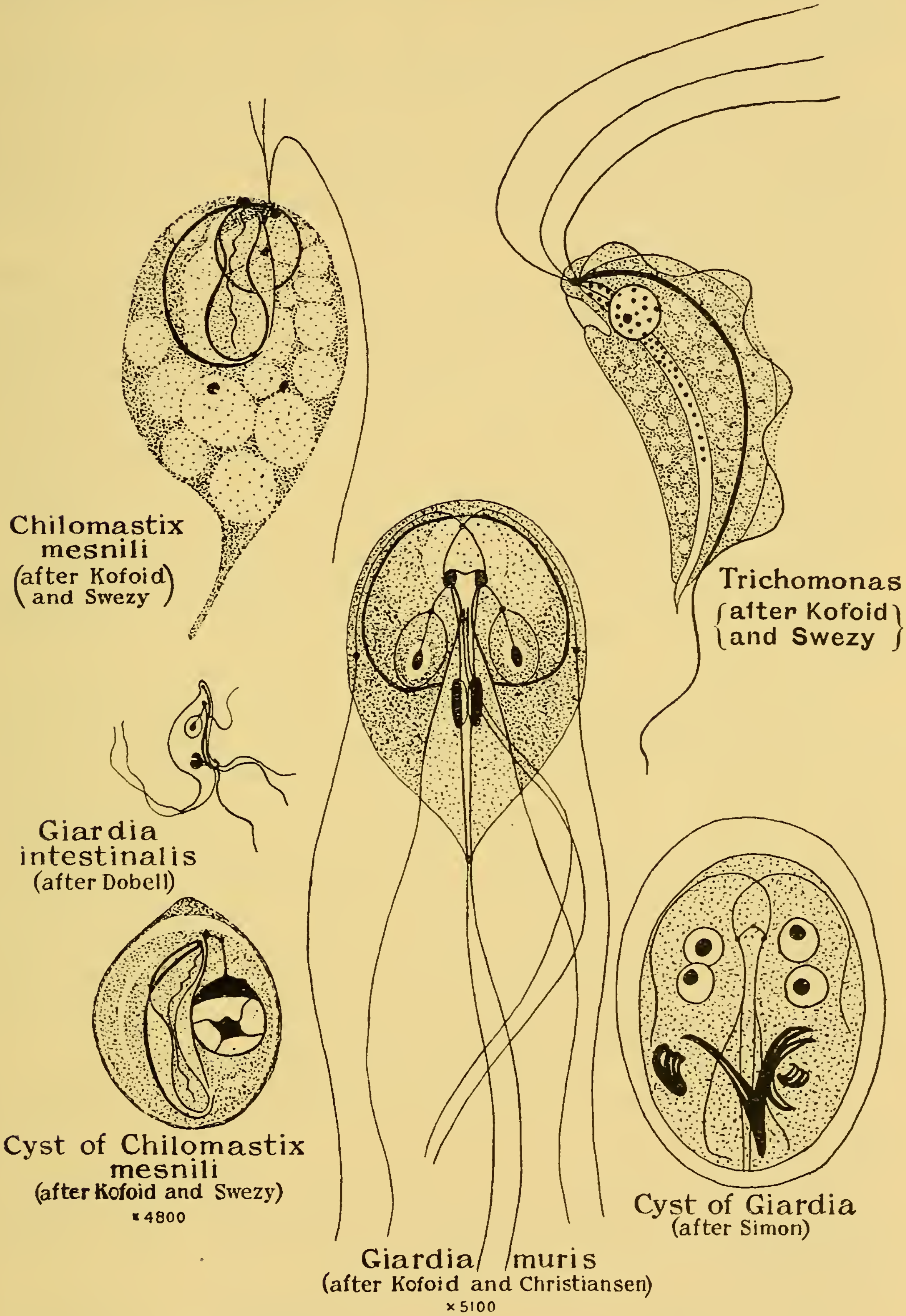



Fig. 7.—Enteric Mastigophora.

In man, two species of Trichomonas occur: *T. vaginalis* lives in the vaginal mucus; *T. hominis* lives in the large intestine,

and is apparently harmless. The latter species may occur also in the buccal cavity, particularly in decayed teeth, and has been recorded as numerous in the stomach in a case of stomach cancer.

Other forms occur in mammals, such as the mouse, guinea-pig, and ruminants. *T. batrachorus* occurs in the cloaca of frogs and toads ; *T. augusta* in the gut of Urodela ; *T. lacertæ* in reptiles. In the cæca of birds there occurs a form with four free flagella and no undulatory membrane, which is termed *Trichomastix gallinarum*.

**Chilomastix** is another genus of Polymastigina recorded from the gut of many different animals. It is a form similar in shape to *Trichomonas*, but is peculiar in possessing a large, somewhat spirally directed groove or mouth along the anterior ventral third of the body; the lips of this groove are supported by fibrillar cytoplasmic structures. There are three flagella, placed anteriorly, and there is no undulatory membrane. The cysts are minute and lemon shaped (Fig. 7).

*C. mesnili* is a common gut commensal of man.

**Giardia** is again a widely distributed genus. It is shaped somewhat like a flattened pear and is distinctly bilaterally symmetrical.

The greater part of the broad end of one surface is occupied by a sucker-like depressed area, by the help of which it is able to cling to the epithelium of the small intestine of its vertebrate host. There are two nuclei, small oval structures situated dorsal to the sucker, and each of the karyosomatic type. Down the middle of the body runs a pair of closely apposed rods, axostyles, in fact. Each ends anteriorly and posteriorly in a blepharoplast. There are four pairs of flagella, one pair situated at the anterior edge of the sucker, two pairs arising in the middle of the posterior margin of the sucker, and a fourth pair forming the posterior pointed tail of the organism (Fig. 7).

*Giardia* in man is typically an inhabitant of the duodenum and upper jejunum ; in the hind gut only the oval cysts are to be found.

General opinion favours the view that it is harmless, although occasionally in children it may be associated with intestinal disturbance.

**Enteric Ciliata,** unlike enteric Mastigophora, are types less complex in structure than the free living forms, and have a comparatively simple life history. Of the large number of species that have been recorded from the animal gut, we need only mention two forms—*Balantidium* and *Nyctotherus*—

which occur together commonly in the alimentary canal of many animals (Fig. 4).

**Balantidium coli,** the largest protozoon in the human intestine, is an irregularly oval organism invested with fine cilia, which, being arranged in parallel rows, give the creature a striped appearance. At one end is the mouth, leading by a short gullet into the endoplasm. The animal is an omnivorous feeder upon micro-organisms and food detritus in the cæcum. It is probably a natural habitant of the pig, from which animal man becomes infected. In man, it may provoke violent dysentery, which may become chronic, accompanied sometimes by ulceration of the bowel wall similar to that provoked by *Entamœba histolytica.* **Nyctotherus** is a smaller form. It is shaped like a bean and has a long mouth extending from the anterior end to the middle of the body. It appears not to cause any intestinal disturbance.

**Enteric Sporozoa.**—Of the seven orders constituting that somewhat artificial assemblage of entozoic forms collectively known as Sporozoa, enteric forms belong, with one exception, to the orders *Gregarinida* and *Coccidia.*

Of the two, the former group is confined in distribution exclusively to Invertebrata, and practically nothing is known as to the influence exerted by its members upon their hosts.

The *Coccidia*, however, occur both in Invertebrata and in Vertebrata, and owing to their excessive prolificacy may cause serious derangement.

The life-cycle of a typical Coccidian may be illustrated by reference to **Eimeria avium,** which infests the domestic galliform birds.

The host becomes infected primarily by swallowing food or drink contaminated with spores of *Eimeria.* The spores dissolve under the action of the bird's digestive juices, and liberate each four minute active banana-shaped organisms—termed sporozoites—which immediately proceed to bore each into a living cell of the gut wall. Once within the cell, the parasite becomes rounded and proceeds to feed and grow at the expense of the cell contents. When these are consumed, the parasite breaks up into a number of minute forms similar to the original sporozoites, and these wriggle away from the parental abode and proceed to attack other cells. Such an asexual phase of multiplication—*schizogony* is the term applied to it—may be repeated several times. Eventually, however, the final product becomes, as it were, too exhausted to carry on the process. Something akin to sexual differentiation seems to occur.

Of the final brood of schizonts, some are small and provided with flagella, others are larger and await in their cell habitat the visit of a flagellated form. There occurs a phenomenon similar to the fusion of a spermatozoon with an egg cell. Instead of a fertilised egg, however, the product of fusion is termed an *öocyst.*

In the öocyst there occurs a division of nucleus and cytoplasm to form four hard cased spores, which pass out to the exterior with the fæces of the bird, and in three or four days elaborate within the spore case two potentially infective sporozoites. The effect upon the host, whether fowl, duck, or pheasant or grouse, is distinctly pathological. Coincident with the schizogony phases, the bird suffers acute and exhausting attacks of diarrhœa, the so-called "white diarrhœa" of poultry. This is accompanied often by a hepatic form of coccidiosis, the liver becoming studded with yellow or white nodules filled with pus swarming with bacteria.

If, however, the bird can survive until the sporogony phase of the parasite occurs, the symptoms disappear and the bird may recover.

Usually, however, reinfection by contaminated food is going on all the time, so that the bird eventually succumbs to the prolonged attacks.

A similar type of coccidiosis may occur in epidemic form in domesticated rabbits, provoked in this case by *Eimeria stiedæ.*

Cattle may become infected also and are very seriously affected.

As regards the species of Coccidia which cause human coccidiosis, present opinion inclines to the view that they are species peculiar to man, and that man is a true host. The best known of them is *Isospora hominis*, which does not seem to be pathogenic.

## CHAPTER IV

### PROTOZOA : Hæmatophilous Forms

PROTOZOA which live habitually in the circulatory system of animals belong exclusively to the two orders Mastigophora and Sporozoa, constituting in each case a sub-order, the **Hæmoflagellata** and **Hæmosporidia** respectively. No hæmatophilous Ciliata or Sarcodina are known.

The **Hæmoflagellata** include particularly the genera *Leishmania* and *Trypanosoma.*

**Leishmania** is a minute oval organism, absolutely without flagellum, which occurs within the cells of the spleen, liver, or bone marrow of vertebrate animals suffering from very definite pathological lesions.

Each is somewhat like a cockle shell in shape, the appearance of the shell hinge being given by a comparatively large stainable body which is undoubtedly the nucleus ; in addition, there is a stainable rod-like body which is homologised with the blepharoplast of other Mastigophora (Fig. 2).

It must be noted that *Leishmania* does not live free in the host body fluids, but is essentially an intracellular parasite within the endothelial cells of the blood and lymph vessels, and within the glandular cells of liver, spleen, and lymph glands. The cell may be distended by a number of the parasites, and such a cell is said to break loose from the tissue and to be carried by the blood stream to other parts of the body. There are three types of Leishmaniasis, corresponding possibly to three species of parasite.

Kala Azar, a dangerous disease of man in the Orient and the Mediterranean area, is associated with *Leishmania donovani,* which occurs in enormous masses in the endothelial cells of the spleen, the liver, and the bone marrow.

Infantile splenic anæmia, occurring in children, and possibly in dogs, in the Mediterranean area, is associated with *Leishmania infantum.*

Oriental sore, Delhi boil, Aleppo button, of Asia, Africa, and South America, is a cutaneous local lesion associated with *Leishmania tropica.*

The inclusion of *Leishmania* in the Mastigophora, despite the absence of flagellum, is based upon the appearance, in sodium citrate cultures of Kala Azar material, of a flagellated organism indistinguishable morphologically from the well-known flagellate, *Herpetomonas*, an active cigar-shaped organism with a single anteriorly situated flagellum (Fig. 2). It is a form commonly occurring in the gut of insects. There can be little doubt, in fact, that this herpetomonad phase of Leishmania is the primary and the infective one, and that it occurs normally in the gut of some arthropodan host, although no such transmitter of the disease has yet been determined. On the other hand, the possibility of infection by fæcal contaminated food or water cannot be negatived.

**Trypanosoma** (Fig. 2) is a genus comprising a number of forms whose flagellated condition is most obvious, the sinuous body being provided with a long flagellum which, commencing from a blepharoplast situated between the central nucleus and the posterior end, runs forward to project beyond the anterior end. The greater part of this flagellum, however, is united to the body by a membrane which, thrown as it is during movement into well-marked pleats or folds, is well termed the **undulating membrane.** This membrane moves in a manner comparable to that of a sail shivering in the wind, that is to say, waves of motion run backwards or forwards along it.

The swimming movements of the trypanosome in the blood of its host are effected, however, rather by the movements of the free tip of the flagellum than by the membrane. The undulations of the membrane certainly cause the body to rotate, and so favour progress through a viscous medium such as blood, but such rotation, unless accompanied by flagellar action, does not move the animal from one position.

Even within the limits of one species there may be great variation in body shape. It may be that slender pointed forms are the normal rapidly multiplying forms, and that when changes in the medium impede the rate of multiplication, short stumpy forms result. Trypanosomes occur exclusively as blood parasites of vertebrate animals, swimming freely in the blood plasma and absorbing the medium by osmosis through the cell wall. In the peripheral blood, however, of an infected animal, trypanosomes may be very sparsely distributed or they may be absent from it altogether, although occurring in the blood capillaries of internal organs. Thus, in Nigeria, trypanosomes occur rarely in the peripheral blood of Sleeping Sickness patients although obtainable by puncturing a lymph

gland. Successful demonstration of the presence of trypanosomes in an animal may necessitate the preparation of artificial cultures of splenic juice or peripheral blood. In such a culture there may appear in a few days a swarm of flagellate forms morphologically identical with the flagellate genus **Crithidia,** a cigar-shaped organism possessing a short undulating membrane, which occurs in the alimentary canal of many insects. There can be little doubt that these culture forms of *Crithidia* represent normal phases in the life-cycle of the trypanosome, and it seems possible that many of the so-called Crithidia species, described from various insect species, are in reality phases in the life-cycle of some trypanosome. On the other hand, where a form of *Crithidia* or of *Herpetomonas* occurs in the gut of a non-bloodsucking insect, the possibility of these being distinct organisms must be postulated.

So far as present knowledge goes, a species of trypanosome is restricted in distribution to a definite host type, generally to a host genus, but morphological distinctions between these species are slight, and it has been found convenient to classify these forms in groups, centring round some definitely established species. There is, for example, the **lewisi** group centring round *Trypanosoma lewisi* from the sewer rat, and comprising *T. duttoni* of the mouse, *T. cuniculi* of the rabbit, *T. rabinowitschi* of the hamster, *T. blanchardi* of the dormouse, and so on. These forms are extraordinarily similar in structure but seem quite unable to live in any other host than the one they normally infect; that is to say, they are probably *biological species.*

Similarly the **brucei** group centres around *T. brucei* and comprises *T. gambiense*, *T. equiperdum*, and *T. evansi.* These are polymorphic forms, including a range of shape between short stumpy aflagellate forms and long slender forms with free flagellum.

There is a small blepharoplast, usually some distance from the posterior end.

**Trypanosoma brucei** is the causative organism of Nagana, the Tsetse fly disease of cattle in Central and South Africa. The disease is not confined to cattle, but occurs in horses, mules, and dogs; possibly in man; at any rate, the trypanosome of Rhodesian sleeping sickness, *T. rhodesiensis*, is said by some authorities to be identical with it.

**Trypanosoma gambiense** is the causative organism of human trypanosomiasis or sleeping sickness, a disease limited to a belt of Central Africa, including particularly the Gambia and Congo regions, Uganda, and Tanganyika; the distribution

coincides with that of the Tsetse fly *Glossina palpalis*, now known to be the chief carrier of infection. The disease comprises two stages :—

(*a*) A long period of intermittent bouts of fever, associated with enlarged lymph glands ; this phase is chronic and may of itself lead, after years, to cachexia and death.

(*b*) A phase characterised by sleepiness and emaciation, and coinciding with the presence of trypanosomes in the cerebrospinal fluid.

*T. equiperdum* causes, in horses, a pathological condition of the mucous membrane, particularly of the urinogenital tract, and appears to be transmitted from one animal to another during copulation.

*T. evansi* is the trypanosome of the camel disease *surra*.

A third group of trypanosomes comprises *T. pecorum* and *T. simiæ*, small forms, which are probably the most virulent of cattle trypanosomes.

A fourth group, again, includes *T. viva*, *T. capræ*, and *T. uniforme*, very active monomorphic forms with simple, slightly developed undulating membrane. They are associated with cattle disease in Uganda.

In addition to the African trypanosomes, reference may be made here to a pathogenic trypanosome of man occurring in Brazil.

This form, **Schizotrypanum cruzi,** is unique in being intracellular.

It occurs occasionally in the peripheral blood, but multiplication occurs within cells in such places as the wall of the heart, the striated muscles, the central nervous system, and various glands. The cell wall swells, becomes cyst-like, and encloses several hundred rapidly dividing trypanosomes.

The disease produced—Chagas disease—may occur in acute form associated with high fever, brain inflammation, swelling of the thyroid glands, spleen, and liver, or in a chronic form associated with myxœdema, goitre, heart trouble, etc.

The trypanosome is carried by a large black and red bug, *Triatoma*, known as the "barbeiro."

In the case of the majority of the African trypanosomes the insect carrier is a species of *Glossina*, the Tsetse fly.

The life-cycle in the invertebrate host is not fully known, but it seems certain that there is no sexual phase there. Observations on *T. gambiense* seem to indicate that the organism multiplies in the insect midgut, very slender forms being produced ; these move forward to the proventriculus and

later to the salivary glands, there to produce crithidial stages; these, again, give rise to the free swimming trypanosome stage resembling that in the vertebrate host, and are probably conveyed into a vertebrate when the fly feeds (Fig. 8).

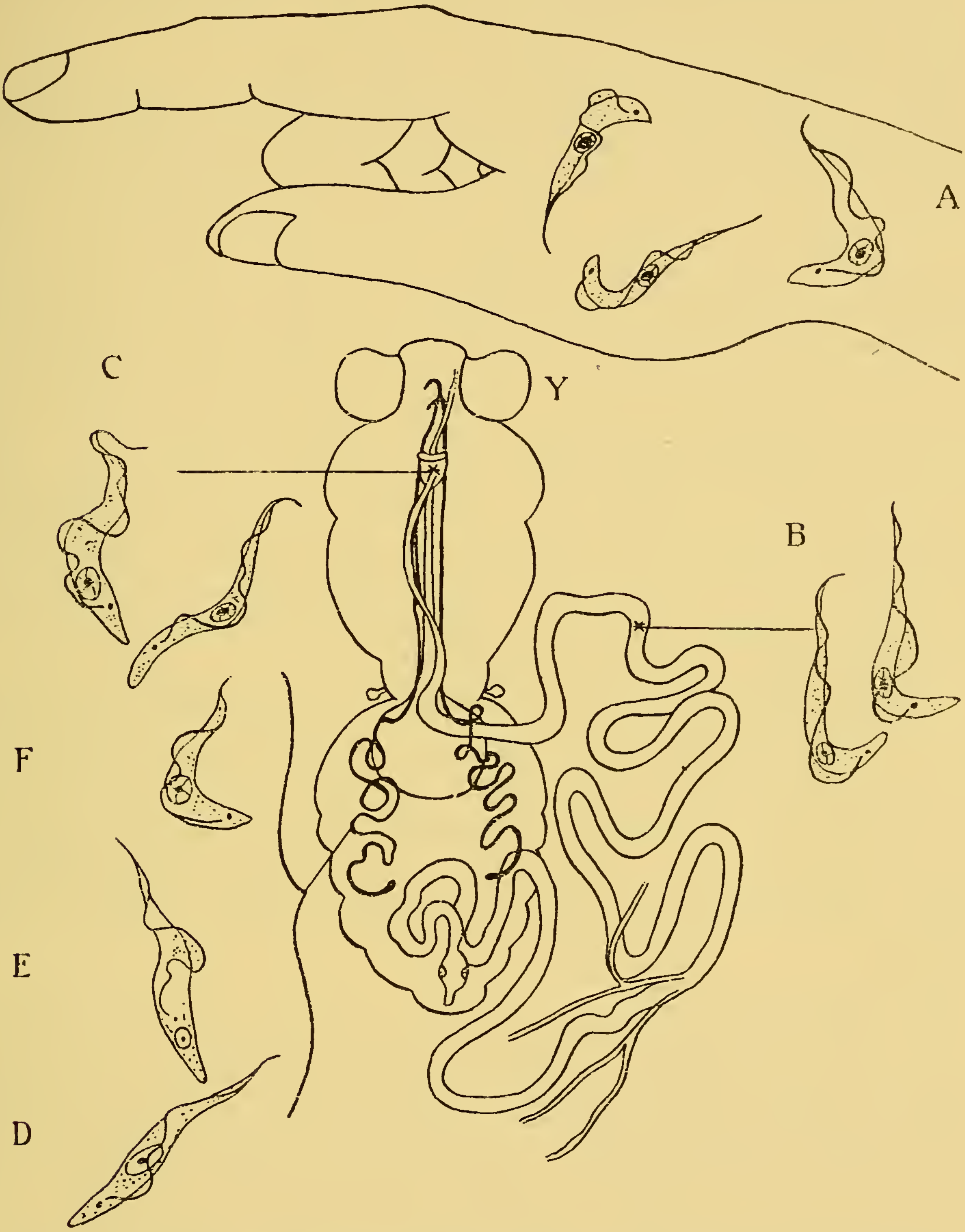



FIG. 8.—Life-Cycle of *Trypanosoma gambiense*. (After various Authors.)

A, Forms in human blood.
B, Forms in midgut of tsetse fly, 48 hours after infection.
C, Long slender forms in proventriculus of the fly, 10-15 days after infection.
D, Forms newly arrived in the salivary glands of the fly, 12-20 days after infection.
E, Crithidial forms in the salivary glands, 2 or 3 days later.
F, Final forms in the salivary glands ready for re-infection of man, 20-30 days after initial infection.

The fly is said not to become infective until after the lapse of thirty days from feeding.

Prophylactic measures against pathogenic trypanosomes fall into three groups :—

(1) Destruction of the insect vector. This question will be discussed in a later chapter.

(2) Destruction of vertebrate reservoirs.

There can be little doubt that trypanosomes, morphologically indistinguishable from such forms as *brucei* and *gambiense*, are present in the blood of wild ungulates in infected districts, particularly in the various species of antelope. Whether these trypanosomes are physiologically identical as well as morphologically identical with the pathogenic forms is another question. Species of trypanosomes are notoriously difficult to distinguish on morphological grounds, but must be separated by their biological properties, such as their pathological effect upon laboratory animals, cross immunity reactions, and so on. Thus if trypanosomes be injected into the blood of an animal immune, owing to previous attack, or even if they come in contact with serum from such an animal, they agglutinate, that is to say, they mass together in large numbers with their flagellated ends projecting from the centres of the mass.

Authorities are divided in opinion as to whether the wild game trypanosomes are identical with those of man and domesticated animals. In any case, a policy of extermination, apart from ethical reasons, is indefensible until it can be shown that trypanosomes, in the absence of large game, will not utilise domestic animals or even small wild mammals and reptiles.

(3) The use of drugs.

The most effective drugs up to now have been arsenical organic preparations injected intramuscularly and tartar emetic injected intravenously. This purely medical question is referred to here because it would seem that trypanosomes can become tolerant towards these drugs, and that such tolerance is inherited, so that "arsenic fast" and "antimony fast" strains of trypanosome arise. There is some reason, however, to think that this acquired immunity is broken by passage through the invertebrate host.

**Hæmosporidia.**—As is the case with their close relatives the Coccidia, hæmosporidian organisms are intra-cellular parasites, in this case within vertebrate red blood corpuscles, and their life-cycle shows an alternation of asexual multiplicative phases (*schizony*) with a sexual phase (*sporogony*).

Unlike the Coccidia, however, transmission of the parasite from one vertebrate host to another is effected by the agency of a bloodsucking invertebrate animal, usually an arthropod, and whereas in Coccidia both schizogony and sporogony occur in the one host individual, in Hæmosporidia these phases require alternation of hosts, schizogony, in fact, occurring only within the vertebrate host, sporogony only within the invertebrate host.

Further, although the term sporogony is convenient to use, the Hæmosporidia do not form spores in the strict sense of the term. The zygote cell which results from the union of male and female gametes, instead of developing a firm cell wall, remains naked, and may be even actively mobile, in which case it is referred to as an *öokinete.* Within the öokinete, however, sporozoites are eventually produced, just as they are produced within the öocyst of the Coccidian.

The three genera of Hæmosporidia which concern man and animals more than any others are **Plasmodium, Hæmoproteus,** and **Babesia.**

**Plasmodium** is the causative organism of the various so-called malarial fevers and agues of mammals and birds. Speaking very generally, it is an amœba-like organism which lives within the red blood corpuscles, which produces a characteristic black pigment, and which is carried from one victim to another by some kind of mosquito. In man three species of Plasmodium may occur, namely, *P. vivax*, of Benign Tertian Malaria; *P. malariæ*, of Benign Quartan Malaria; *P. falciparum*, of Malignant Tertian Malaria.

In a tertian fever the febrile attacks recur every other day; in a quartan fever they recur every fourth day.

The genus is not restricted to man; *P. kochi* is recorded from chimpanzees, *P. canis* from dogs, *P. equi* from horses. An allied genus, *Proteosoma*, causes a form of malaria in birds.

Infection of man follows upon the introduction into his blood, in the infected saliva of an Anopheline mosquito, of several thousand minute cigar-shaped *sporozoites*, which each actively attack and enter a red blood corpuscle. Each sporozoite then becomes rounded, but retains a certain amount of amœboid activity, particularly in the case of *P. vivax.* It proceeds to absorb the contents of the cell, and is full grown in twenty-four to forty-eight hours after entrance, or seventy-two hours in the case of the quartan fever organism. The signet-ring appearance of the parasite, due to the appearance of a pigmented peripheral zone around a non-stainable central vacuole, and to the peripheral position of the nucleus, gradually

becomes obliterated by the deposit of black pigment so characteristic of *Plasmodium*, and the full-fed organism appears as an angular pigmented mass filling the cell membrane (Fig. 9, D).

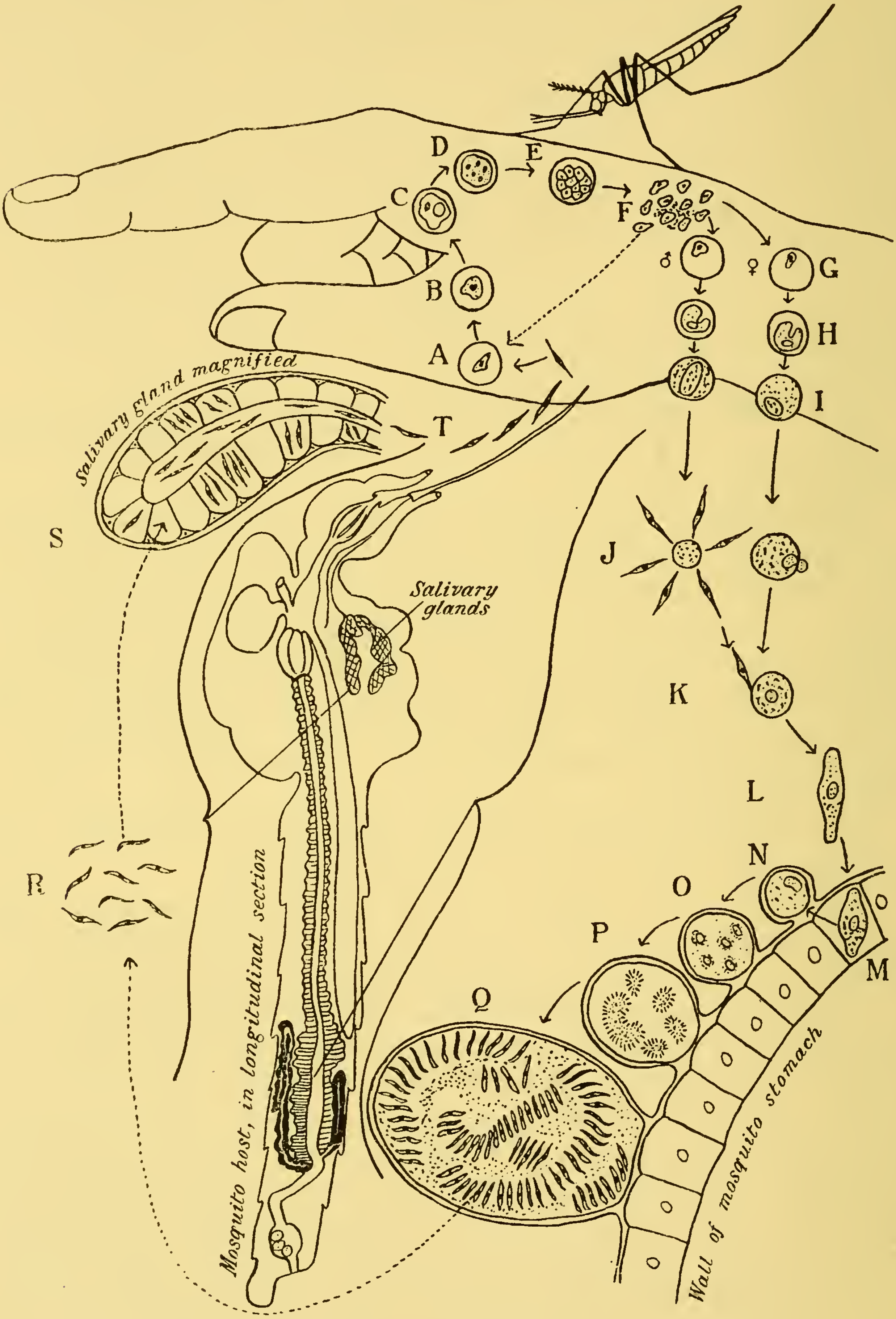



FIG. 9.—Life-Cycle of *Plasmodium*.

A-F, Schizogony. Production of merozoites in blood of man.
G-T, Sporogony. Production of sporozoites in mosquito.

The full-fed parasite now breaks up, by successive divisions, into a rosette-like mass of minute cells similar to the original sporozoites; these burst out from the corpuscle and proceed each to infect another host cell. This process of *schizogony*, as it is termed, or liberation of *merozoites*, reinfects the host severely, and after a period of two to three weeks, during which successive schizogonies are occurring, the host shows response to each new schizogony by developing a temporary but acute attack of high fever, induced doubtless by the liberation of the waste products of cell destruction into the blood plasma.

After a succession of such asexual phases of multiplication, there appear in the blood corpuscles certain forms of modified merozoite which are preparatory to the sexual phase of the life-cycle and can be termed *gametocytes*. Why some merozoites become gametocytes and others do not, is uncertain. Two kinds of these gametocytes are produced. They are rounded bodies, crescentic in *P. falciparum*, and the two kinds differ in size and pigment distribution (Fig. 9, H, I).

No further development of them can occur unless they become swallowed by an Anopheline mosquito, in whose midgut each gametocyte sheds the encircling host corpuscle and proceeds to develop further.

The smaller type or *microgametocyte* undergoes what used to be termed "exflagellation," that is to say, it gives rise to four to eight thread-like cells which are the male gametes, analogous to spermatozoa (Fig. 9, J).

The larger type or *macrogametocyte* does not undergo division but prepares, somewhat like a maturing egg cell does, for the reception of a microgamete. The product of the union of micro- and macro-gamete is an elongate, active, somewhat worm-like *öokinete* (Fig. 9, L), and can bore through the midgut wall and encyst between muscles and external epithelium of the gut, as a spherical body, termed an *öocyst*. There may be 200-500 such öocysts in one insect individual, and each grows comparatively enormously and bulges into the body cavity.

Within each cyst the nucleus and cytoplasm divide to produce a number of cytoplasmic nucleated areas termed *sporoblasts*, within each of which, again, several hundred thread-like *sporozoites* are formed (Fig. 9, Q).

Rupture of each cyst liberates these thread-like forms and they squirm their way into the salivary glands of the insect, from thence to be passed into another human host.

The cycle in the mosquito requires eight to twelve days.

The mosquito is now infective, and probably remains so for the rest of its life.

The distribution of the various species of *Plasmodium* is, of course, dependent upon the distribution of the particular species of mosquito which can act as host. External temperature, however, plays a not inconsiderable part in their geographical distribution, since exflagellation requires a temperature above a certain minimum. Thus *P. falciparum*, of malignant tertian malaria, is widely distributed over the tropics and sub-tropics; but since its sexual phase requires a minimum temperature of 18° C., it is not likely to become established in temperate latitudes. *P. vivax* and *P. malariæ*, however, may occur in such latitudes, and the quartan form is in fact more a disease of temperate than of tropic zones.

The establishment of *Plasmodium* as the causative organism of malarial fever was made by the French scientist Laveran. The association of mosquitoes with Plasmodium transmission, although suggested by Manson, was not made until early in the present century, when Ross in Bombay showed the association of avian malaria with Culicine mosquitoes. Later he established the cycle of human malaria in the mosquito genus *Anopheles*, but was partly forestalled by the Italian workers Grassi and Bastianelli, who put malaria upon a definite zoological and cytological basis, and studied the benign tertian and quartan forms, as well as malignant tertian malaria. Both Ross and Grassi have contended for priority of discovery. Ross undoubtedly was the first to suggest the mode of transmission, but the exact scientific proof and zoological presentation was made by Grassi.

**Hæmoproteus** occurs exclusively in the red blood corpuscles of birds as a large bean-shaped or dumb-bell shaped organism, the so-called *Halteridium* stage. This represents a gametocyte stage. No schizogonous phase has been discovered in these forms.

When blood containing these stages is taken into the insect host, which is some species of Pupiparid fly, ripening and copulation of the gametes takes place in the insect midgut.

The öokinetes, however, are injected back into a bird and, by some means not yet clear, obtain admission to leucocytes in the capillaries of lungs, spleen, kidney, and bone marrow, where they become sac-like and undergo sporogony. The sporozoites pass into the peripheral blood and infect red blood corpuscles.

**Babesia** and **Piroplasma** are minute parasites occurring within the red blood corpuscles of mammals, chiefly Ruminants,

Carnivora, and Rodents, and causing certain severe forms of cattle disease, notably the so-called Red-water fevers and Tick-fevers of cattle-rearing countries. They are certainly transmitted by ticks, but neither schizogony nor sporogony has been established in their life-cycle, and they do not produce pigment. Their relationship to other Hæmosporidia is, in fact, obscure.

They occur in the blood corpuscles in two forms, namely :—

(*a*) Rounded forms, often ring-like, like young Plasmodium schizonts, but not pigmented ; the hæmoglobin of the injured corpuscles escapes into the plasma and is excreted in the urine, tinging it red.

(*b*) Relatively larger pear-shaped forms, occurring singly or in two, four, or even eight in number, within one red corpuscle (Fig. 3).

There appear to be no human parasites included in the Piroplasmidæ, although one form, *Bartonella bacilliformis*, the organism of Oroya fever of man in Peru, is sometimes admitted into the group.

Other genera and species of Piroplasmidæ are *Piroplasma canis*, which causes malignant jaundice in dogs ; *Piroplasma bigemina*, the organism of Texas cattle fever, the first protozoan disease known to be transmitted by an arthropod, in this case the tick *Boophilus* ; *Piroplasma bovis* causes red-water fever in European cattle ; *Theileria parva* is the organism of East Coast or Rhodesian red-water fever of cattle in Africa, India, Macedonia, and Transcaucasia.

**Spirochæta.**—No discussion of hæmatophilous protozoa can be considered complete which does not include some mention of these pathogenically important forms, even if their exact relationship to Protozoa is somewhat debatable.

Generally speaking they are minute, corkscrew forms which are extremely active (Fig. 10). In certain respects they resemble bacteria, notably in the lack of a differentiated nucleus, the lack of sexual reproduction phases, and the division by transverse fission. On the other hand, the possession of something recalling the undulating membrane of trypanosomes, the occasional occurrence of longitudinal fission, and their chemotropic reactions, suggest somewhat that they should be classed with the Protozoa, particularly since they are often transmitted by arthropodan hosts. They are not all hæmatophilous ; some occur in the pus of cutaneous and mucosal ulcers, some in the contents of the animal gut.

Their average length is about 20 microns, but some forms,

commensal in Mollusca, and some free living forms, may be as long as 200 microns. The majority of the pathogenic forms are scarcely visible under the highest microscopic powers.

Three types of diseases are caused by pathogenic spirochætes:—

(1) Relapsing fevers, characterised by anæmia, splenic enlargement, and febrile symptoms. The fever will occur

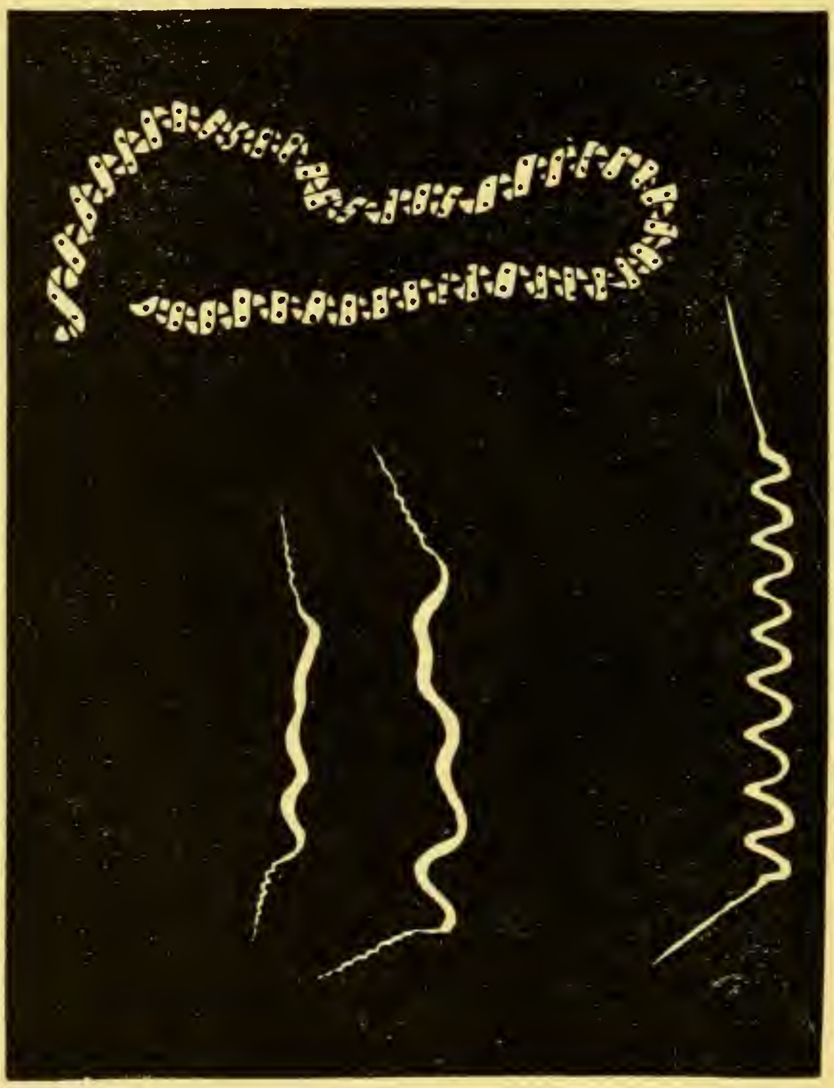


FIG. 10.—Types of Spirochætes.

for several days, be followed by a period of well-being, and then re-occur.

The organisms of relapsing fevers belong to the genus **Spironema.**

The East and West African relapsing fever is caused by *S. duttoni*, transmitted by the tick *Ornithodorus moubata.* European relapsing fever is caused by *S. recurrentis,* and is probably transmitted by body lice.

Although the tick host is a bloodsucker, the spirochæte is not transmitted via the proboscis of the tick, but is ejected

in the fæces and in the secretion from the coxal glands. It is thus necessary that the tick puncture become contaminated by the fæces or gland secretion deposited near it.

In the human host the organism inhabits the blood plasma. In the tick it penetrates the gut and occurs in the hæmocœl as black granules which even pass into the developing eggs so that ticks from infected parents may transmit the disease.

In the same category as relapsing fevers may be placed :—

(*a*) Rat bite fever, caused by *Spirochæta morsus muris* present in the blood of the rat and, by gum hæmorrhage, contaminating the teeth and so becoming introduced into man.

(*b*) Yellow fever, demonstrated by Noguchi in 1919 to be caused by **Leptospira icteroides**, a spirochæte only 4-9 microns in length and capable of passing through a bacterial filter. It is transmitted by the mosquito *Aëdes argenteus.* The spirochætal nature of yellow fever is now, however, discredited by some workers.

(2) The second type of spirochæte disease is characterised by the occurrence of local lesions, followed by general constitutional symptoms, followed finally by localisation of the causative organisms in special organs or tissues. The three main diseases of this type are syphilis, yaws, and jaundice.

Syphilis is caused by the spirochæte **Treponema pallidum,** discovered by Schaudinn and Hoffmann in 1905 in various syphilitic lesions. It averages 8 microns in length, has six to twelve short, sharp, geometrically regular spirals, and a straight filament at each end.

*T. pallidum* is able to produce lesions in almost any organ of the body, but eventually becomes localised in some special organ or tissue, such as the skin, bones, central nervous system, arteries, and so on.

Yaws or frambesia of tropical countries has a causative organism—*Treponema pertenue*—almost indistinguishable from that of syphilis. In fact it is possible that yaws is a variety of this disease.

(3) The third type of spirochæte disease is characterised by the presence of local ulcerations of the skin or mucous membranes. Thus *Spirochæta schaudinni* produces skin ulcers in the tropics. *Sp. bronchialis* attacks the respiratory tract, producing a certain type of bronchitis. *Sp. orientalis*, the cause of "ulcerating granuloma of the pudenda," is localised in ulcerations of the skin and mucous membranes of the external genital organs.

## CHAPTER V

### HELMINTHES : The Flukes

THE term Helminthes in general may be said to refer not so much to all the various types of animal popularly designated as " worms," but rather to the two zoological phyla *Platyhelminthes* or flatworms, and the *Nemathelminthes* or roundworms.

The term flatworm, again, comprises a wide range of creatures very diversified in appearance and habit ; many are free living, creeping over stones and plants in marine or fresh-water pools by means of a coating of cilia which work in the moist exudation from numerous skin glands ; others are ecto-parasitic on skin, gills, or in the body orifices of vertebrate animals, and have lost such motile organs as cilia, but gained, in compensation, organs of adhesion in the form of suckers and hooks ; others, adapted to a life spent within the vertebrate alimentary canal, have lost even alimentary canal and vascular system.

The flatworms fall readily into three classes, well demarcated from each other by important morphological features.

The *Turbellaria* or eddy worms are free-living, ciliated, leaf-shaped forms found gliding like living films over stones and weeds in marine and fresh-water pools, and varying in size from a quarter of an inch long to tropical terrestrial forms nearly a foot long.

The *Trematoda* or flukes are parasitic forms which are without cilia, but which are provided with adhesive organs usually termed " suckers," a quite unsuitable name, since these are merely muscular cups without any ability to suck in food-stuffs.

The *Cestoda* or tapeworms are internal parasites of vertebrate animals and have diverged very greatly from the ancestral type if this latter form was similar, morphologically, to the present-day *Turbellaria.*

**Trematoda.**—Flukes retain, to a large extent, the leaf or tongue-shaped appearance characteristic of free-living forms, but the absence of cilia, the limitation of muscular mobility, and the absence of gaudy coloration characteristic of Turbellaria, quite precludes any possibility of confusing the two groups.

They are usually small, the majority being a quarter to three-quarters of an inch in length, although *Nematobothrium*, a

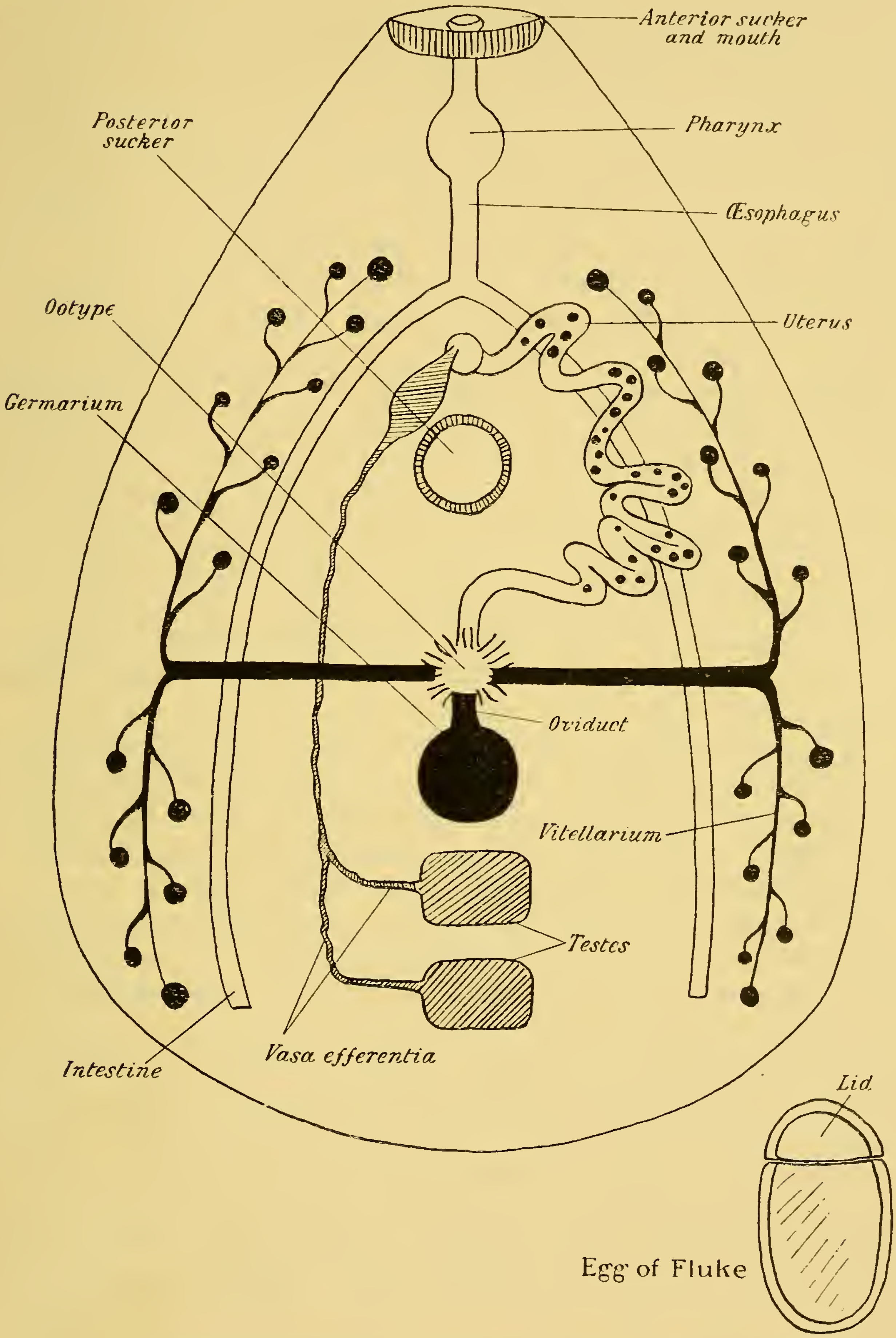



FIG. 11.—Reproductive System of a Distomid Fluke. (Diagrammatic.)

worm-like form on the gills of the tunny, may reach three feet in length.

The mouth, terminal or ventro-terminal in position, leads

by way of a muscular, sucking pharynx into a forked alimentary canal, each branch of which ends blindly ; the absence of anus is characteristically platyhelminthian. The food consists of mucus, blood, epithelial cells, or the intestinal juices of the host, and is thus of a kind easily assimilated ; probably little or no solid matter remains to be defecated ; the bulk of the nutriment circulates in soluble form through the spongy tissue between gut and body wall, and the expulsion of surplus nitrogen in the form of some substance similar to guanine or xanthine is carried out almost entirely by the excretory system. The **excretory system** is of the type peculiar to flatworms. Scattered throughout the spongy tissue that fills up the body space not already occupied by alimentary canal or reproductive organs are numerous hollow cells. Within each of the cells a flickering bunch of cilia produces a flame-like effect. Each so-called "flame cell" communicates by means of a straight, exceedingly thin capillary tube, with a longitudinal collecting duct. The collecting ducts, generally two in number, unite at the posterior end of the animal into a common trunk, which, again, may discharge into an excretory bladder and so to the exterior.

The animal, as in the case of most flatworms, is hermaphrodite, and the arrangement of the **reproductive organs** is somewhat complex (Fig. 11).

The male organs comprise two testes, variable in shape, lying either side by side, or one behind the other ; each communicates by means of a fine **vas efferens** with a single median **vas deferens** which runs to the genital aperture and ends in a protrusible hooked organ termed the **cirrus** or penis.

The arrangement of the female organs will be understood more clearly if it be realised that the ovary is divided into two physiologically distinct portions. There is a **germarium** or egg-producing portion, represented by a median compact or sometimes branched structure posterior to the ventral sucker. There is a **vitellarium** or yolk-producing portion, represented by a large number of spherical glands on either side of the animal. The ducts from these scattered yolk glands converge on each side into a duct which meets the duct from the germarium within a chamber, into which a number of shell-secreting glands open. Into this chamber, the so-called **öotype,** there open also certain other ducts to provide for admission of spermatozoa and removal of surplus yolk. Thus in ectoparasitic forms a paired vagina provides for admission of spermatozoa, and a median **Laurer's canal** conducts surplus yolk either to the exterior or into the gut. In the öotype the egg cell is

fertilised, receives its yolk, and becomes surrounded by a shell which has a lid. The complete eggs are then transferred to the tubular **uterus,** along which they travel to the exterior. In endoparasitic forms, fertilisation is effected by spermatozoa which have entered the uterus, there being no other passage to the exterior.

**Classification.**—The most logical classification of flukes is based upon the number and character of the adhesive organs.

The order **Heterocotylea** comprises forms which possess a large posterior sucker, sometimes subdivided into lesser suckers ; in addition, there may be two small anterior suckers. These forms are ectoparasitic upon skin, gills, and in the mouth and bladder of the lower vertebrate animals. The life-cycle is straightforward, the egg giving rise to a simple ciliated larval form, which swims about in the water until able to attach itself to another host individual.

As the parasite utilises only one host individual, the life-cycle is termed **monogenetic.**

The order **Aspidocotylea** comprises a few little known forms which possess each a very large ventral sucker, sometimes divided into compartments ; these forms are endoparasitic.

The order **Malacocotylea** comprises forms with a variable arrangement of suckers ; thus there may be a tiny anterior sucker surrounding the mouth and a large posterior terminal sucker ; this is the **amphistomid** condition ; or the posterior sucker may be situated only a little way from the anterior one, on the ventral surface ; this is the **distomid** condition ; or again, only the anterior sucker surrounding the mouth may be present, the so-called **monostomid** condition ; or the body may be divided by a constriction into two regions, of which the anterior one carries two minute suckers, and the posterior one bears the reproductive organs ; this is the **holostomid** condition. Malacocotylean forms are endoparasitic either in the gut or associated glands and ducts, or in the lungs, or kidney, or urinary bladder, or even the blood, of vertebrate animals.

The life-cycle shows a regular alternation between a sexual form, parasitic in the vertebrate, and a series of asexual forms, usually termed *larvæ*, occurring either in water or in an invertebrate host.

The eggs hatch under moist, external conditions and give rise to a ciliated larval **miracidium** stage. This is a fragile, short-lived form which endeavours to find and enter a secondary host, usually one that is small, widespread, and easily pene-

trated, and usually one that is liable to come in contact, as by becoming swallowed, with the primary host; in this secondary host the larva can encyst and await passively the advent of a primary host individual.

In the majority of cases, the miracidium after entering the digestive gland of a fresh-water mollusc degenerates into a sort of hollow bag of cells, termed the **sporocyst,** rarely exceeding a few millimetres in length at first, but sometimes increasing in size at the expense of the snail's tissues. This sporocyst is able to produce, by budding from its internal wall, a number of mulberry-like balls of cells which develop into small, tubular sacs not unlike the parent sporocyst but possessing a simple pharynx and intestine; these are termed **rediæ.** Similarly, each redia may bud off a fresh generation of rediæ, or it may produce a type of larval stage termed a **cercaria.** The cercaria has a round or oval body similar in internal structure to that of the adult fluke, but it has a boring spine within the anterior sucker, has eye spots, and has a propelling organ or tail; in some cases the tail is absent, the larva then being designated as a **cercariæum.** This cercaria is really the youngest form of the sexual stage; if the tail be present, a free-living phase is passed through. That is to say, the cercaria leaves the molluscan host and swims around in the surrounding moisture. Eventually, however, it penetrates some aquatic creature, discards its tail, and encysts, to await passively the transmission to the primary host in which alone it can attain maturity. In some cases the second intermediate host is dispensed with, and the cercaria encysts in the water or on some water plant, and is thus taken up in direct fashion by the primary host when it eats or drinks. The use of the term "encysted cercaria" for this condition is incorrect. The creature is a miniature fluke which only requires to grow in size and to differentiate its sexual organs. A better term for it is that suggested by Stossic of **Agamodistomum.**

It is disputed whether the life-cycle of an endoparasitic trematode is a complicated metamorphosis, that is to say, a developmental change in the life-cycle of the one individual, or whether it is a true alternation of one sexual and two asexual generations, or whether, regarding the cells in the sporocyst which give rise to rediæ, and the cells in the redia that give rise to further rediæ or to cercariæ, as parthenogenetic ova, the life-cycle is not an alternation of one sexual with two parthenogenetic generations.

**Economic Aspect.**—The Trematodes which are of serious

pathogenic importance to man and domesticated animals are all Malacotylean forms. In particular, two are of outstanding interest, namely, the liver fluke of the sheep and the blood fluke of man, known respectively as *Fasciola* and *Schistosoma*.

**The Liver Fluke.**—"Liver rot" of sheep is caused by the presence in the bile-ducts and branches of the hepatic portal vein of large numbers of a distomid Trematode—**Fasciola hepatica**; a milder form of liver disease is produced also in some countries by the smaller fluke—**Dicrocœlium lanceolatum**—but not in Great Britain.

Though occurring chiefly in sheep, particularly sheep pastured in damp localities, the liver fluke is not specifically restricted to sheep, but is found not uncommonly in cattle, and less commonly in horses, goats, camels, rabbits, deer, kangaroos, etc. In rare cases it may occur in the bile-ducts of man, such infection being due probably to the eating of infected watercress. In the Lebanon district of Syria, *Fasciola hepatica* frequently occurs in considerable numbers in the pharynx of man, giving rise to severe inflammation and swelling which may endure for several days, until the symptoms are relieved by vomiting; this so-called "Halzoun" disease is due to the eating of raw infected goat's liver.

The range of the liver fluke extends over the whole of Europe, including particularly England and Central France; it occurs over Northern Africa; it is common in North America, where it coexists in distribution with the scarcely less common *Fasciola magna*, a parasite of deer. It is less common in South America, and has been reported in Australia. The distribution is local and restricted to damp or marshy localities where the water snail *Limnœa* is abundant.

*Fasciola hepatica* is about three-quarters of an inch to an inch and a half long, is flattened, oval, and dirty-white in colour. The anterior portion projects somewhat beyond the rest of the body, like a head on shoulders. The anterior sucker is terminal, small, circular, and contains the mouth; the posterior sucker is larger and lies in the middle line, just behind the junction of the anterior projection and the shoulders.

*Dicrocœlium lanceolatum* is smaller, pointed at each end, and lacks the shouldered appearance. The body is translucent, so that the internal organs are readily seen. The two intestinal trunks are not provided with lateral branches as in *Fasciola*. In both genera the internal morphology is of the typical trematode type.

**Life History.**—Our knowledge of the life-cycle of *Fasciola*

*hepatica* is very complete, owing to the work of Thomas, Leuckart, Ercolani, and others.

The eggs are laid in enormous numbers in the bile-ducts of the host, pass down the alimentary canal and are expelled with the fæces. Given a sufficiently moist environment and a mean temperature of 70°-75° F., the eggs will hatch, the ciliated miracidium larva pushing aside the lid of the egg and escaping into the surrounding moisture. The lease of life of this ciliated stage is about eight hours ; that is to say, within that period of time it must penetrate an intermediate host or perish. The intermediate host in this case is a species of water-snail, the little water-snail of damp meadows, *Limnœa* ; in Europe, *Limnœa truncatula* ; in Hawaii, *Limnœa oahuensis* ; in North America, *Limnœa viator* ; in Australia, *Limnœa brazieri*.

In the case of *Dicrocœlium* the host would seem to be a species of *Planorbis*, *P. marginatus* or *P. complanatus*.

Within the respiratory chamber of the mollusc the larva loses cilia and eyespots and becomes just a hollow, cylindrical sac or *sporocyst*, from whose walls mulberry-like masses of cells arise and become *rediœ* ; these are cylindrical sacs, not unlike the sporocyst stage, but possessing a pharynx and a simple straight intestine. These redia, if the environmental conditions be dry, as in summer, give rise to a number of daughter rediæ ; but if the moist environment of a wet autumn or winter be available, each redia gives rise to a number of *cercariœ* larvæ, tailed motile forms with a forked gut and two suckers ; these forms leave the snail, swim about for some time in the surrounding moisture—thus becoming distributed—and then encyst upon the stems of the grasses and meadow plants, generally just at the point where the stem rises above the moisture level ; that is to say, in an ordinary damp meadow the encysted cercariæ will occur on the lower portions of the grass stems, so that close-cropping herbivores, such as sheep, are more likely to become infected than are cattle or horses.

**The Effect on the Sheep.**—The general effect on the sheep is to induce progressive pernicious anæmia culminating fatally in most cases.

Infection is believed to occur most frequently in autumn, but the migration of the embryo parasites from the host alimentary canal to the liver does not apparently provoke any characteristic symptoms. About December or January, however, there is a period of anæmia, accompanied by abnormal fattening and by feverish symptoms, and characterised by the

presence of *Fasciola* eggs in the animal's fæces. Then follows a period of severe emaciation, accompanied by diarrhœa, wool-shedding, abortion among pregnant ewes, and a characteristically dropsical condition of the tissues below the jaw, in evidence when the head is lowered in grazing. Death eventually ensues from exhaustion, or in some cases there is spontaneous recovery. The parasite remains in the host from nine to fifteen months.

The post-mortem appearance of the liver is that of an abnormally swollen and soft structure with the surface rough instead of smooth; later there is great vascular congestion of the organ, the bile-ducts are dilated and inflamed and crowded with flukes; the ducts tend to become calcified, and this calcified condition will persist even in a sheep that has recovered.

**Preventive Measures.**—There is no royal remedy for the elimination of the parasites from the host, although claims have been made for common salt and for extract of male fern.

An infected pasture can be attacked very successfully, however, by anti-snail measures comprising treatment of the land with salt or with iron sulphate, combined with drainage operations.

**Other Flukes of Domesticated Animals.**—The liver of herbivorous mammals is liable to infection by some or other species of *Fasciola*, *Dicrocœlium*, or *Fasciolopsis*; the liver of carnivorous mammals by *Opistorchis*, *Metorchis*, or *Bilharziella*.

*Opistorchis felineus* of the dog and cat has been recorded occasionally in man. The host is believed to become infected by eating certain cyprinid fish.

The gut of domesticated birds, such as the duck, goose, swan, is infested by a holostomid fluke, *Echinostomum echinatum*, whose anterior body region is armed with large numbers of sharp, backwardly directed spines.

The lungs of pig, dog, and cat are commonly infected in oriental countries, and even in the United States, by a broadly oval fluke, *Paragonimus westermanni*, the provoking agent of pulmonary distomatosis.

The alimentary tract of herbivorous mammals is liable to harbour species of *Amphistomum* and *Gastrodiscus*.

**Schistosoma.**—The genus *Schistosoma*, whilst possessing the oral and ventral suckers characteristic of distomid flukes, is remarkable amongst them in that:—

(*a*) There are distinct sexes; in the male, the lateral edges of the body behind the posterior sucker curl inwards to form

a tube which encloses the thread-like female; the male has therefore a cylindrical shape (Fig. 12).

(*b*) The alimentary canal bifurcates in front of the ventral sucker, but the two branches unite into a single tube lower down the body, behind the ovary.

(*c*) There is no muscular pharyngeal bulb at the commencement of the œsophagus; since the cercaria in structure is a miniature adult, this absence of muscular pharynx serves also to distinguish a schistosomid cercaria from that of other distomid flukes.

**Schistosoma hæmatobium** is the provoking agent of a widespread endemic disease, variously termed bilharziosis, schistosomiasis, endemic hæmaturia, and so forth, in Northern Africa, especially Egypt; the disease occurs also in South Africa, Arabia, India, Persia, Cyprus, etc., and evidence as to its antiquity has been afforded by the discovery of calcified Schistosoma eggs in the kidneys of two mummies of the twentieth dynasty (1250-1000 B.C.).

The adult flukes, which are about half an inch long, occur, as permanently coupled males and females, in the abdominal veins of man, especially in the veins comprising the portal system and the capillary veins of the bladder.

A certain amount of danger to the host may result from the blockage of capillary vessels by masses of adult worms, but the serious effects upon the host result from the presence of the eggs. These are comparatively large and provided with a stout terminal spine. They occur in masses in the capillary vessels of the liver, intestine, kidney, and bladder, and cause lesions not only through mechanical blocking of the blood-vessels but through laceration of the tissues by the spines of the eggs. The mucosa of the bladder, in particular, becomes acutely inflamed, and the presence of blood and eggs in the urine makes diagnosis of the disease easy and accurate. Coterminous in distribution with this urinary form of bilharziosis caused by *Schistosoma hæmatobium*, but occurring also in the West Indies and Venezuela, there is an intestinal form of bilharziosis, characterised by intestinal inflammation and by the occurrence, in the fæces of the host, of schistosoma eggs which have a *lateral* spine. This form of the disease is now regarded as being provoked by a distinct species—**Schistosoma mansoni.** The third species of *Schistosoma* is endemic in man and in domesticated animals in Japan, China, Philippines, and possibly elsewhere in the Far East. This is **Schistosoma japonicum.** The eggs have a little lateral knob instead of a spine, and occur

in the fæces of the host, but may occur in masses blocking up the bile-ducts, the capillaries of spleen, pancreas, and even the brain.

Knowledge regarding the life-cycle of the genus *Schistosoma* has been accumulated largely as a result of the observations and experiments of Miyairi, Leiper, and others in Japan, and

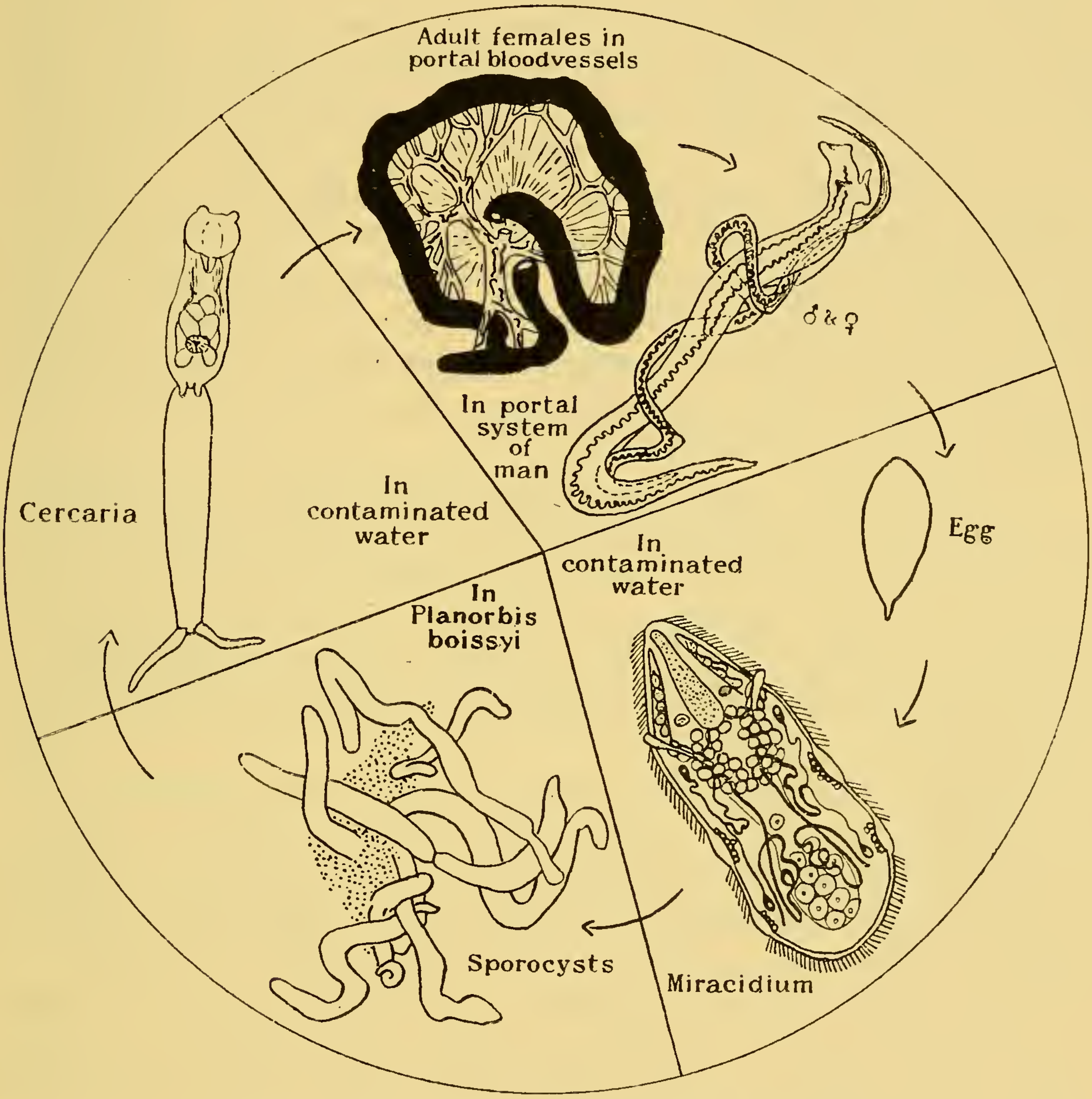



Fig. 12.—Life-Cycle of *Schistosoma hæmatobium*.
(Miracidium after Seymour Sewell; other stages after Leiper. Not to scale.)

of Sonsino, Looss, Lortet, Leiper, and others in Egypt. The difficulty of establishing the life-cycle details of any one species is intensified by the considerable number of species of *Schistosoma*, which occur in mammals and birds. Thus in Egypt, in addition to *S. hæmatobium* and *S. mansoni* of man, there occur *S. bovis* of cattle and *Bilharziella polonica* of ducks.

The general life-cycle story of species of Schistosoma is probably similar for all species (Fig. 12).

The egg gives rise to a ciliated miracidium, which dies within twenty-four hours unless it has found a molluscan host. The miracidium in this latter event enters the digestive gland and gives rise to a long tubular sporocyst. This gives rise to similar tubular daughter sporocysts with delicate transparent walls. These migrate into the tissues of the digestive gland, which swells greatly.

These sporocysts have neither oral sucker nor alimentary canal, and must absorb their nutriment through their walls. They can wriggle along quite readily through the gland tissue. The sporocysts produce cercariæ characterised by a long Y-shaped tail and an absence of suctorial pharynx. These cercariæ are discharged from the snail in little clouds into the water. They must enter their vertebrate host within forty-eight hours or perish, and they enter the host directly through the skin of the body or through the mucous membranes of the mouth, to which they can adhere by their suckers and through which they bore very rapidly.

A *Schistosoma* species does not limit itself to any species of mollusc, but usually there is some molluscan species which is more liable to infection than others. In the case of *S. hœmatobium*, the favourite molluscan hosts are species of *Bullinus*; in the case of *S. mansoni*, species of *Planorbis* are concerned; in the case of *S. japonicum*, species of *Limnœa* and *Blanfordia* are involved.

Prophylactic measures against *Schistosoma* infection therefore should comprise :—

(1) Avoidance of ablution with water liable to contain cercariæ unless previously treated with antiseptics such as cresylic compounds, of which as low a dilution as one part in ten thousand of water is effective in destroying cercarial stages.

(2) Avoidance of drinking water from infected sources, unless such water has stood for forty-eight hours, or has been boiled or otherwise sterilised.

(3) Destruction of molluscan hosts either by exposure to sun temperatures induced by intermittent irrigation, or by chemical agents such as copper sulphate.

**Other Flukes of Man.**—A considerable number of flukes have been described as occurring in man, but chiefly in tropical countries.

In China, Japan, the Philippines, Formosa, occurs **Paragonimus ringeri,** living in cavities in the lungs and provoking a characteristic blood-spitting ; the expectorations are a peculiar reddish-brown colour and contain dark-brown

fluke eggs. The molluscan host is said to be *Melania libertina*, and the emerging cercaria attacks a second intermediate host, a fresh-water crab, in whose digestive gland the young fluke is found within a cyst. When swallowed by a crab-eating animal the cyst wall becomes dissolved and the active liberated cercaria bores through the intestinal wall, wanders about the abdominal cavity, eventually gets into the pleural cavity and penetrates into the lungs. A closely allied species of lung fluke, *Paragonimus kellicotti*, occurs in hogs in the United States.

Similar in distribution to *P. ringeri* is the liver fluke of man, **Clonorchis sinensis.** In Japan the percentage of infection among the population is said to be 60 per cent. and in Korea 80 per cent. It occurs also in dogs and cats. The related cat fluke, *Opisthorchis felineus*, of Europe and America also occurs occasionally in man. All these flukes live in the gall bladder and bile-ducts and cause serious mechanical obstruction, resulting in enlargement of the liver and bloody diarrhœa. Infection results from eating certain fresh-water fishes in whose muscles the encysted cercariæ occur.

The sporocyst stages of *Clonorchis sinensis* are believed to occur in the snail *Bythinia striatula* var. *japonica*, at any rate in Japan.

*Fasciolopsis buskii* is the large intestinal fluke of man in oriental countries. It is probably a normal habitant of the pig.

*Heterophyes heterophyes* occasionally occurs in the intestine of man in Egypt. The tiny fluke *Yokagawa yokagawa* is widely distributed in the Far East as a parasite of the human intestine. Infection arises from the eating of raw fish.

# CHAPTER VI

## HELMINTHES : The Tapeworms

Apart from a few forms that consist of a single joint, a tapeworm always shows three distinct regions :—

(1) A **scolex,** or organ of attachment ; a bulb-shaped structure bearing organs of adhesion in the form of four cup-shaped suckers (in the tænoid type) or two or four slit-like grooves (bothriocephaloid type), and generally possessing one or two circlets of hooks surrounding a swollen apical portion termed the **rostellum.**

(2) A **neck,** or slender unsegmented region merging into

(3) The **strobila,** or chain of flattened quadrilateral joints (**proglottids**), each joint being sexually complete.

Alimentary canal and related structures are completely lacking.

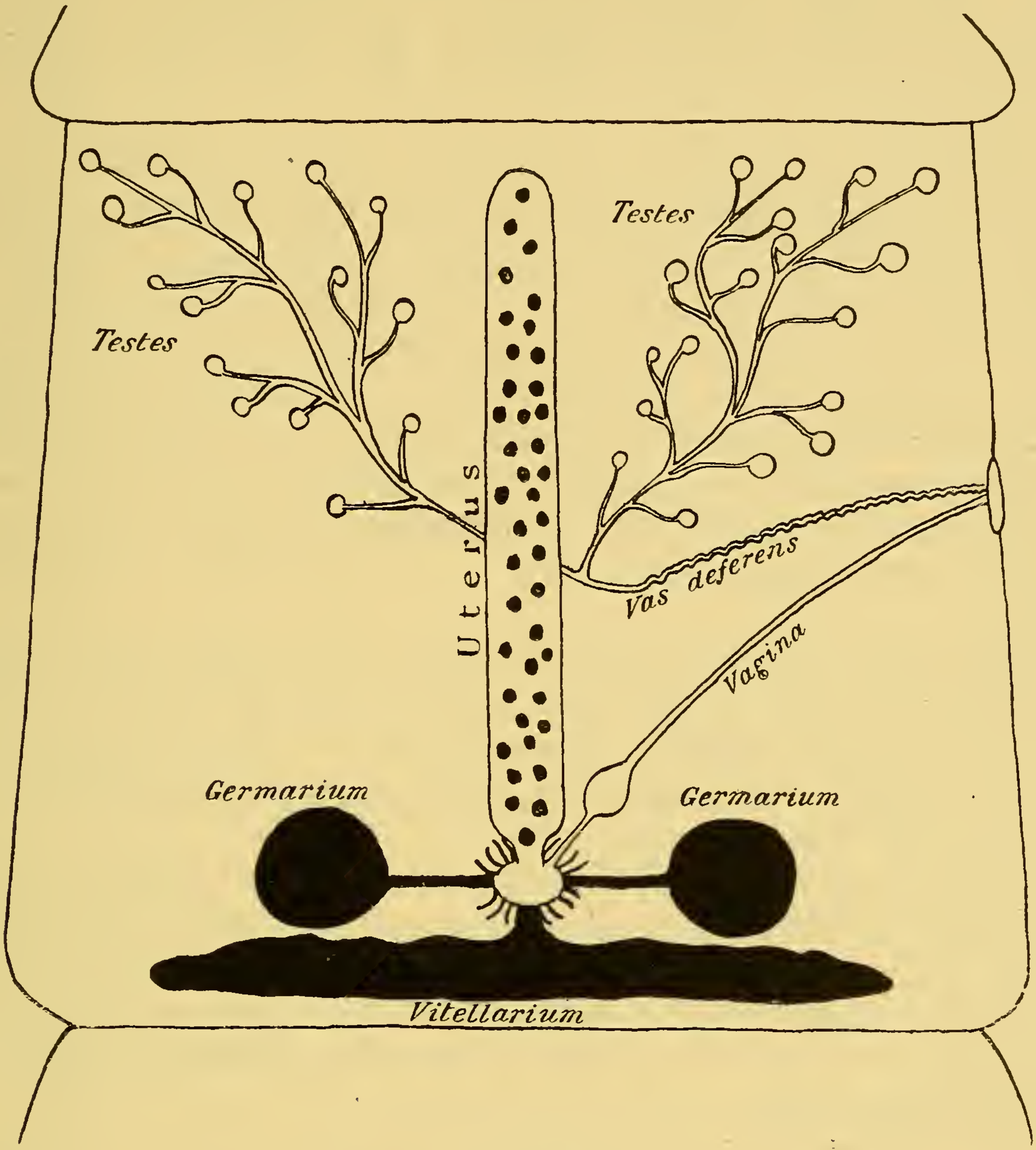
The **excretory system** resembles that described for Trematoda ; the capillaries may, however, form a network, and the collecting tubes are typically four in number, two on each side, running the full length of the worm ; in the scolex the two vessels on each side unite by means of a loop ; in the first formed proglottis they open into a small bladder and so to the exterior by a pore in the middle of the posterior edge of the proglottis.

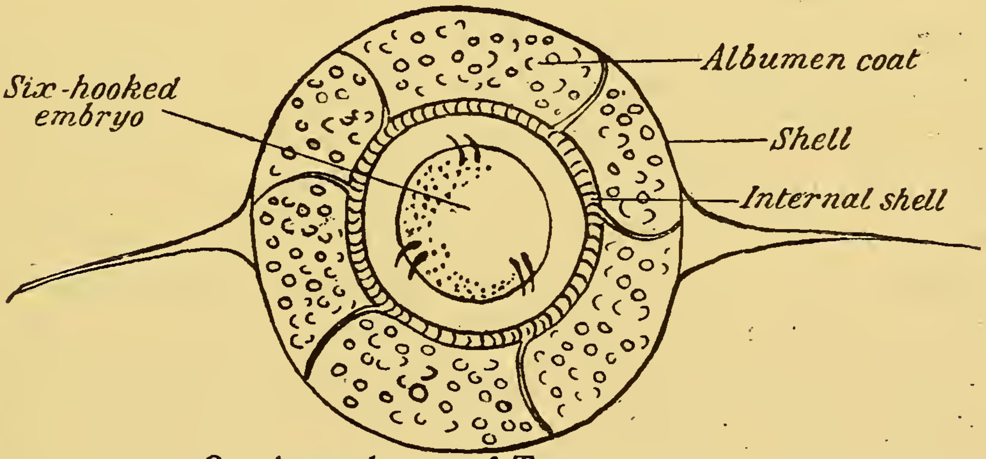
The **nervous system** consists of a number of longitudinal nerve fibres running parallel with the outer edge of the excretory canals and united by cross fibres (commissures) in the scolex.

The **proglottids** vary in number, according to species, from four or five to several thousands, and arise in succession from the neck region, so that the oldest is the one farthest away from the scolex. Usually, if the number of joints is large, the youngest are transversely oblong, the middle ones square, and the old ones longitudinally oblong.

The proglottids resemble each other and resemble flukes in the structure of the cuticle, the muscular system, and the possession of spongy internal tissue ; they differ from each other, however, in the degree to which the **reproductive organs** are developed.

It must be borne in mind that each proglottis is not merely hermaphrodite ; it is *protandrously* hermaphrodite, that is to




Onchosphere of Tapeworm

FIG. 13.—Reproductive System of a Tapeworm Proglottis.

say, the male organs appear and ripen before the female ones do ; a proglottis fairly near the scolex will therefore show greater development of male than of female organs ; a pro-

glottis in the middle of the chain may have male and female organs fairly equally developed ; then, as the proglottis becomes older, the female organs increase in size and development until in the fully mature proglottis the enormously enlarged gravid uterus may quite obliterate the remaining male and female organs.

If, as is conventional, the surface of the tapeworm upon which the uterine pore opens be termed ventral, then the male organs may be said to occupy the dorsal portion of each segment, the female organs the ventral. The **male** organs consist of numerous small spherical **testes,** scattered in the parenchymatous tissue ; each testis is connected by a small tubule to similar tubules from the other testes and the whole network converges to a convoluted collecting duct or **vas deferens.** This latter may or may not dilate to form a **vesicula seminalis,** but always terminates in a protrusible penis or **cirrus,** enclosed in a cirrus pouch.

The male genital aperture opens along with the vaginal aperture into a common chamber, the border of which is raised to form a genital papilla ; the position of this latter structure on the proglottis is of great importance in the identification of tapeworm species (Fig. 13).

Several methods of fertilisation have been observed. The proglottis may fertilise itself with or without making use of its penis ; or the proglottis may be cross fertilised by a proglottis of the same chain or of a different chain ; or where two sets of organs occur in the one proglottis, cross fertilisation between the two sets may occur.

The **ovaries** are usually two in number, and are comparatively large, compound, tubular glands ; there is one common **oviduct,** which, a short distance from the ovaries, receives the **vagina,** a straight tube parallel in course to the vas deferens ; the united ducts continue as the fertilisation canal to the tubular **uterus,** receiving on the way the common duct from a series of **yolk glands,** and numerous ducts from the **shell glands** (Fig. 13).

Thus the egg cell, after fertilisation, receives a certain amount of yolk, then receives shell material at the point of entry of the shell gland ducts, and then moves into the uterus. The uterus, as the proglottis ages, becomes larger and develops lateral branches, to accommodate the accumulating mass of eggs. It may open by a mid-ventral pore, or may be blind, in which case the escape of eggs has to await the decay and dissolution of the proglottis.

Actually the egg stage has developed so far by the time it

is free from the proglottis that it contains a larva ready to hatch, a spherical organism with three pairs of hooks. This larva or **onchosphere,** as it is termed, is surrounded before hatching by a covering or membrane composed of radially arranged rods. The true egg shell has really gone (Fig. 13).

**Life History.**—Tapeworms are parasites of the alimentary canal of vertebrate animals, and in most cases of the intestinal portion of the canal. The comparatively large size and restricted habitat of the parasite would thus render the development of eggs and embryos *in situ* a condition of affairs highly prejudicial to the existence of the species. We find, therefore, as in flukes, that embryonic and larval development takes place, in most cases, outside the habitat of the adult, and to compensate for this, the degree of probability of the immature form returning to the similar conditions of habitat, necessary for maturation, is intensified not only by the production of large numbers of eggs, from seven to twenty millions yearly in the case of *Tœnia solium*, but also by utilisation of an intermediate host, a host that is liable to come into intimate contact with the primary host. In fact, the primary host is in most cases a carnivorous animal, the intermediate host an animal commonly preyed upon by the primary host; and just as the muscular portion of the intermediate host is more likely to become swallowed by the carnivore than any other portion of the body, so the immature stage of the tapeworm, that adapts itself to life in the intermediate host, occurs usually in the animal's muscles or in the connective tissue.

The egg is the only stage that can exist outside a host animal.

The eggs pass out from the intestinal habitat of the adult in various ways. In the case of *Dibothriocephalus*, the "broad tapeworm," the uterus possesses an opening to the exterior and the eggs are deposited in the intestine of the host and evacuated with the fæces; if the environment be sufficiently moist, the eggs will hatch after a fortnight, and the ciliated, slow-swimming organism that emerges may, by some means not yet known, secure ingress to the muscles of a fish. The ciliated organism, it may be noted, consists of a capsule—*the embryonic capsule*—bearing cilia and enclosing a spherical *embryo* possessing three pairs of hooks. It differs, therefore, from the ciliated miracidium of a Trematode.

The embryo plus capsule constitute the so-called *onchosphere.*

In those tapeworms which do not possess a uterine pore, the eggs reach the exterior in an indirect fashion. The terminal

proglottids, as they become ripe, break away from the strobila, aided possibly by the peristaltic contractions of the host's intestine, and either force their way independently through the anal sphincter muscle or pass out in short chains with the fæces. The eggs are freed by the decay and disintegration of the proglottis wall, which may occur whilst still in the host's gut or outside the host, or by the digestive juices of the intermediate host. In any case the onchosphere is not ciliated and can only enter the intermediate host by the mouth in food or drink.

Feeding experiments with *Tœnia crassicollis* of the cat, whose intermediate host is the mouse, indicate that the embryo emerges from the shell about the middle of the host's small intestine, tears its way through the intestinal wall to the intestinal blood-vessels by means of its hooks, and is then carried by the portal vein to the liver ; embryos leave the liver with the circulation and may be distributed throughout the tissues of the body. Rarely do they remain in the cavity of the intestine, as does *Hymenolepis murina* of the rat, but settle in the muscles, mesenteries, etc. Such active migration of large numbers of embryos through the tissues may give rise to febrile symptoms—the so-called " acute cestode tuberculosis " —sufficiently intense to cause death of the host animal, or the further development of the embryo in its final resting-place may prove fatal if localised in the liver or brain. Once the embryo has come to rest, it develops into the so-called bladder worm or larva or **metacestode stage.** The term bladder worm derives its name from the condition shown by metacestodes of the genus *Tœnia*, where this stage does consist of a small bladder about the size of a pea. Protruding into the cavity of the bladder, and surrounded by fluid, there occurs a scolex in no way different from the scolex of an adult worm except that, since it is an invagination from the wall of the bladder, it is turned inside out. Actually, this is the scolex of a future worm and only requires the stimulus of gut conditions in the appropriate carnivorous host, in order to become everted from the bladder, so that it can attach itself to the gut wall and proceed to bud off a chain of proglottids.

In many tapeworm metacestode stages, this bladder-like appearance is not so apparent as in *Tœnia.*

There is, in the first place, the *solid* metacestode, the **plerocercus** (spherical) or the **plerocercoid** (elongated), where the scolex is derived directly from the onchosphere, and is pushed into the posterior portion of the solid larval body. Secondly,

there are forms which are *bladder-like* ; the bladder is formed directly from the onchosphere and is thus a primary structure ;

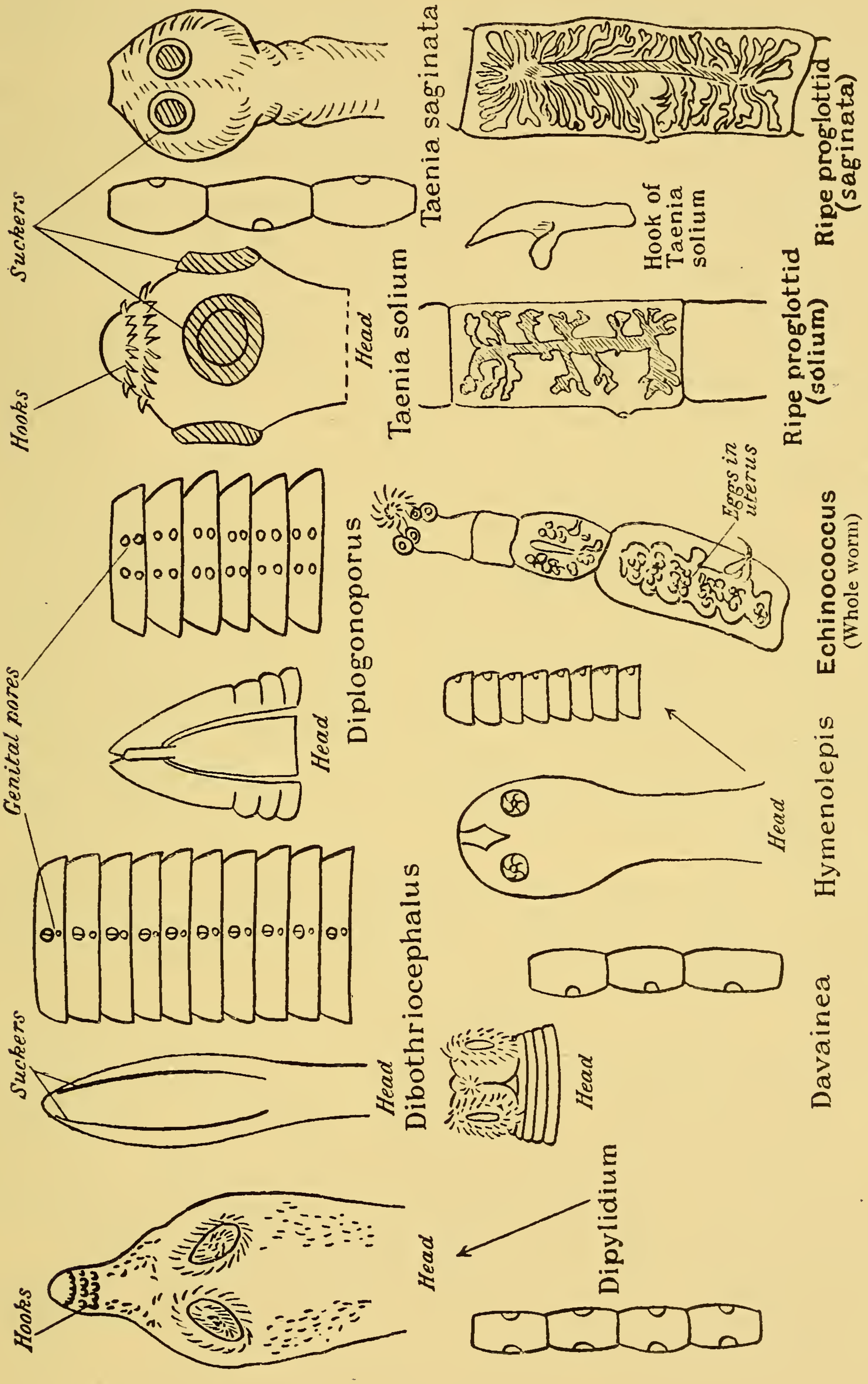



Fig. 14.—Diagnostic Features of the More Important Tapeworm Genera.

the invaginated scolex is formed from the bladder and is thus a secondary structure. Of these forms, the **cysticercoid** type

has the bladder but slightly developed, and may have a tail-like appendage ; the **cysticercus** type consists of a bladder and one scolex ; the **cœnurus** type has a bladder with many scolices ; and the **echinococcus** type has a bladder containing daughter bladders each possessing numerous scolices (Fig. 15).

In practically all cases the metacestode must reach the alimentary canal of the primary host before it can mature.

We find, therefore, a definite correlation between primary and intermediate hosts ; tapeworms of cats spend the metacestode period in mice ; tapeworms of dogs and foxes have metacestode stages in rabbits and hares ; tapeworms of man have metacestode stages in the pig or ox. In a few cases the intermediate host seems to be dispensed with. *Hymenolepis murina*, for example, a small tapeworm of rats and mice, has its metacestode encysted in the intestinal wall of the same host. In the case of such genera as *Moniezia*, *Thysanosoma*, *Stilesia*, and *Anoplocephala*, all parasitic in the alimentary canal of herbivorous animals, the intermediate host is unknown, and the question arises as to whether this host may not be some small mollusc or insect from which the metacestode can actively migrate in order to encyst upon herbage and so infect the herbivore. Such active migration has been observed in the case of the metacestode of the fish tapeworms *Ligula* and *Schistocephalus*.

**Bionomics.**—As we have already noted, the adult tapeworm is, with few exceptions, a parasite of the vertebrate gut, nourishing itself upon the gut contents which it absorbs through its whole surface.

On the other hand, the metacestode stage is a non-feeding stage thus rarely occurring in the gut of its host, but being found normally in the muscles, mesenteries, occasionally in the liver, lung, and brain.

From a pathenogenic standpoint, therefore, the metacestode is much the more injurious of the two in its effects upon the host ; the tapeworm stage, whilst provoking undoubtedly gastero-intestinal troubles, nervous symptoms, and more or less anæmia, is rarely sufficiently injurious to bring about the death of its host. The metacestode is, however, the cause of several fatal diseases of man and domesticated animals.

**Classification.**—If we exclude the few primitive, unisegmental forms, we can divide the genera of tapeworms between two distinct orders :—

(*a*) *Pseudophyllidea* (bothriocephaloid type) with two slit-like elongated grooves on the scolex, with a uterine opening, and with a solid larva from which the scolex of the future

adult is formed directly. Examples—*Bothriocephalus*, *Diplogonoporus*.

(*b*) *Cyclophyllidea* (tænioid type) with four round suckers, no uterine opening, and a vesicular larval stage; the scolex of the adult is formed from the bladder and thus indirectly from the larval one. Examples—*Dipylidium*, *Hymenolepis*, *Tœnia*, *Davainea*, *Moniezia*.

The *Pseudophyllidea* includes the family *Bothriocephalidœ*, certain members of which are of considerable economic interest.

**Dibothriocephalus latus,** the so-called "broad tapeworm" of dog, cat, and man, is particularly prevalent in French Switzerland, in the Baltic regions of Germany and Russia, and in Turkestan and Japan. It is readily distinguished from other tapeworms of man by the egg-shaped scolex with its two slit-like adhesive organs, and by the short, broad proglottids, each with uterine pore and genital papilla close together in the middle line.

The metacestode is of the plerocercoid type, and occurs in the liver, muscles, and other organs of various fresh-water fishes, particularly pike, perch, trout, and grayling. It has been shown recently that a second intermediate host is necessary; that the newly hatched embryo is preyed upon by a species of the water flea *Cyclops*, and undergoes a preliminary development within it, the so-called "procercoid larva" stage; if the infected *Cyclops* is swallowed by a fish, the parasite migrates into the muscles of the fish and remains there until eaten by the mammalian host.

Related to *Dibothriocephalus* is *Diphyllobothrium mansoni* of cats and dogs. There is a procercoid stage in *Cyclops leuckartii* and a plerocercoid stage in several animals, including man, but especially in frogs and snakes.

Other plerocercoids have at different times been recorded from man, and are grouped under the name **Sparganum proliferum** or *Sparganum mansoni*. The former type occurs in the form of little oval capsules occurring in thousands in the subcutaneous tissues and in the internal organs. Each organism is white, flattened, and irregular in shape. The irregularity in shape arises from a habit of budding off supernumerary heads which may become detached, leave the cyst, and form separate capsules. Nothing is known as to the life-cycle in which these forms are stages, but there is a possibility that infection in man arises from the consumption of raw fish.

Of the families which constitute the Cyclophyllidea, the family *Tœniidœ* is of considerable economic importance.

It is divided usually into three sub-families, namely :—

The *Anoplocephalinæ*, a family of tapeworms whose metacestode stage has in no single case been observed nor the intermediate host discovered.

The tapeworms occur in herbivorous animals and include *Moniezia* of sheep and cattle, *Thysanozoon* of sheep and pigs, *Stilesia* of sheep, *Anoplocephala* of horses and asses, and *Ctenotœnia* of the wild rabbit.

The *Tœniinœ*, a family of well-known tapeworms whose metacestode stage is a cysticercus, a cœnurus, or an echinococcus stage, occurring, as does the tapeworm, in some species of mammal.

The family includes *Tœnia solium* and *Tœnia saginata* of man, whose cysticercus stages occur in the pig and the ox respectively ; *Tœnia serrata* and *Tœnia marginata* of the dog, with cysticercus stages in the rabbit and in the sheep or ox respectively ; *Tœnia crassicollis* of the cat, with a cysticercus stage in the rat or the mouse ; *Multiceps* of dogs, with a cœnurus stage in ruminants and rodents ; *Echinococcus granulosus* of the dog, with an echinococcus stage in any mammal.

It may be noted that the tapeworms of the genus *Tœnia* are restricted each to a particular species of host or to a few closely allied species. Thus *T. solium* and *T. saginata* occur only in man, and attempts to establish them in other animals have always failed.

*T. marginata*, very similar morphologically to *T. solium*, is not known from animals other than the dog and wolf ; it cannot develop in man. On the other hand, *T. serrata* occurs in three species of *Canis*, two species of *Felis*, and in the gray fox (*Urocyon*). *T. crassicollis* is known from ten species of *Felis* and from *Mustela erminea*.

The cysticercus stage, however, may be considerably less restricted in choice of host. Thus *Cysticercus cellulosœ* of *T. solium* can develop in no fewer than eleven different animals. *Cysticercus bovis* of *T. saginata* can develop in the muscles of the ox, pronghorn antelope, giraffe, and llama. *Cysticercus tenuicollis* of *T. marginata* occurs in the liver and abdominal cavity of probably all ruminants, in seven genera of primates (except man), and in several species of squirrel.

Petrunkevitch has made the suggestion that those species with the widest range of intermediate hosts may be the oldest, and puts forward the further suggestion that the human species have arisen as mutants from one of the still existing dog tapeworms, probably *T. marginata*.

The *Dipylidiinæ* is a family of tapeworms each generally provided with a long protrusible hooked rostellum, whose cysticeroid stages occurs usually in some arthropod, the tapeworm stage occurring in birds or mammals. The family includes *Dipylidium* of the dog, cat, man, with intermediate stage in the dog-flea or louse; *Hymenolepis gracilis* of ducks and geese, with a metacestode in various fresh-water crustacea; *Hymenolepis murina* or *nana* of rodents whose metacestode occurs also in the gut of the *same* host as the tapeworm stage; *Hymenolepis diminuata* of rats and mice, with metacestode in the larva of *Asopia farinalis*, the meal-moth.

Some of these forms may now be discussed.

**Tænia** is a genus characterised by the possession, in the tapeworm stage, of four circular adhesive cups, the so-called "suckers," on the scolex; by a non-protrusible rostellum; and by the genital apertures of the proglottids being lateral and alternately placed on one edge or the other.

Of the two species which infest man, **Tænia solium** is distinguished by the double circlet of hooks on the scolex, by the ripe uterus having seven to ten lateral branches arranged dendritically, by the ripe proglottids being expelled with the host's fæces in short chains, and by the mature proglottis being quadrilateral (Fig. 14).

**Tænia saginata** has no hooks, has fifteen to thirty lateral branches of the ripe uterus, arranged dichotomously, has a pumpkin seed-like mature proglottis, which escapes from the host gut usually singly (Fig. 14).

Of the two species, the latter is the more common, possibly because beef infected with the bladder worm stage is more difficult to detect than is infected pork, owing to the bladder worm stage of *Tænia saginata* being much smaller than that of *Tænia solium*. The genus **Multiceps** has three species, *multiceps*, *serialis*, and *gaigeri*, all occurring in dogs only, all very similar to one another morphologically, and none differing greatly from the genus *Tænia*. The *cœnurus* type of metacestode is, however, characteristic of this genus.

In the species *M. multiceps* the cœnurus may occur in the brain or spinal cord of ruminant animals, horses, and even man. In fact, the embryos of this species perish if carried by the blood stream to any other organ than the central nervous system.

*M. serialis* has its cœnurus stage in the connective tissues of rodents, especially species of *Lepus*, the rabbit.

**Cœnurus cerebralis,** the cause of considerable mortality

amongst sheep, is a bladder worm about the size of a hen's egg which occurs frequently in the brain of young sheep, less frequently in the brain of goat or ox, and rarely in that of the horse. The victim becomes infected by eating herbage contaminated with the eggs of *Multiceps multiceps*, a tapeworm of sheep dogs and foxes. The embryos bore their way through the gut wall, and are probably carried to every organ of the host by the blood currents, but only those which reach the brain seem able to develop further. If one or more embryos reaches the brain, their gradual development brings about a distinct pathological reaction on the part of the host, constituting the disease known in Great Britain as "gid" or "staggers." If the brain contains a considerable number of larvæ, say ten to twenty, the symptoms shown are those of general paralysis; there is general weakness and emaciation, partial blindness, and loss of the sense of balance; death may come about from acute brain fever, and the symptoms, in fact, may be confused with those of sunstroke or of meningitis.

If, however, only one or two cœnuri be present, the victim, in addition to the symptoms catalogued above, constantly jerks the head from side to side, and in the later stages walks round and round in circles, or even pivots on its hoofs, until paralysis and death intervene.

No certain surgical or medicinal treatment is known. Removal of a portion of the frontal bone in the hope of localising and then destroying the "bladder" is a heroic method frequently practised by shepherds, but with rare success.

Preventive measures are simple, consisting chiefly of precautions against the contamination of tapeworm by sheep dogs through eating infected brains. If the brains and spinal cords of diseased sheep were carefully burned, and measures taken to free farm dogs from the tapeworm stage, the disease could be stamped out of every infected district with ease, and a considerable source of loss to the agriculturist thus averted.

**Davainea** is an interesting genus of Tæniine tapeworm characterised by the possession of hooks on the suckers as well as on the rostellum (Fig. 14). It is a parasite usually of birds; thus *Davainea urogalli* infests the grouse.

One species, *Davainea madagascarensis*, a small form about ten to twelve inches long, is found commonly in children in many tropical seaports and on ships, and a suggestion has been made that some species of cockroach may act as intermediate host.

**Echinococcus granulosus** (Fig. 14) is the smallest species of

*Tænia*, measuring, as it does, only one-tenth to one-fourth of an inch in length, and having only three to four proglottids; it may occur in enormous numbers in the small intestine of the dog, jackal, wolf, or puma, but has never been found in man.

The intermediate stage, *Echinococcus polymorphus*, is found

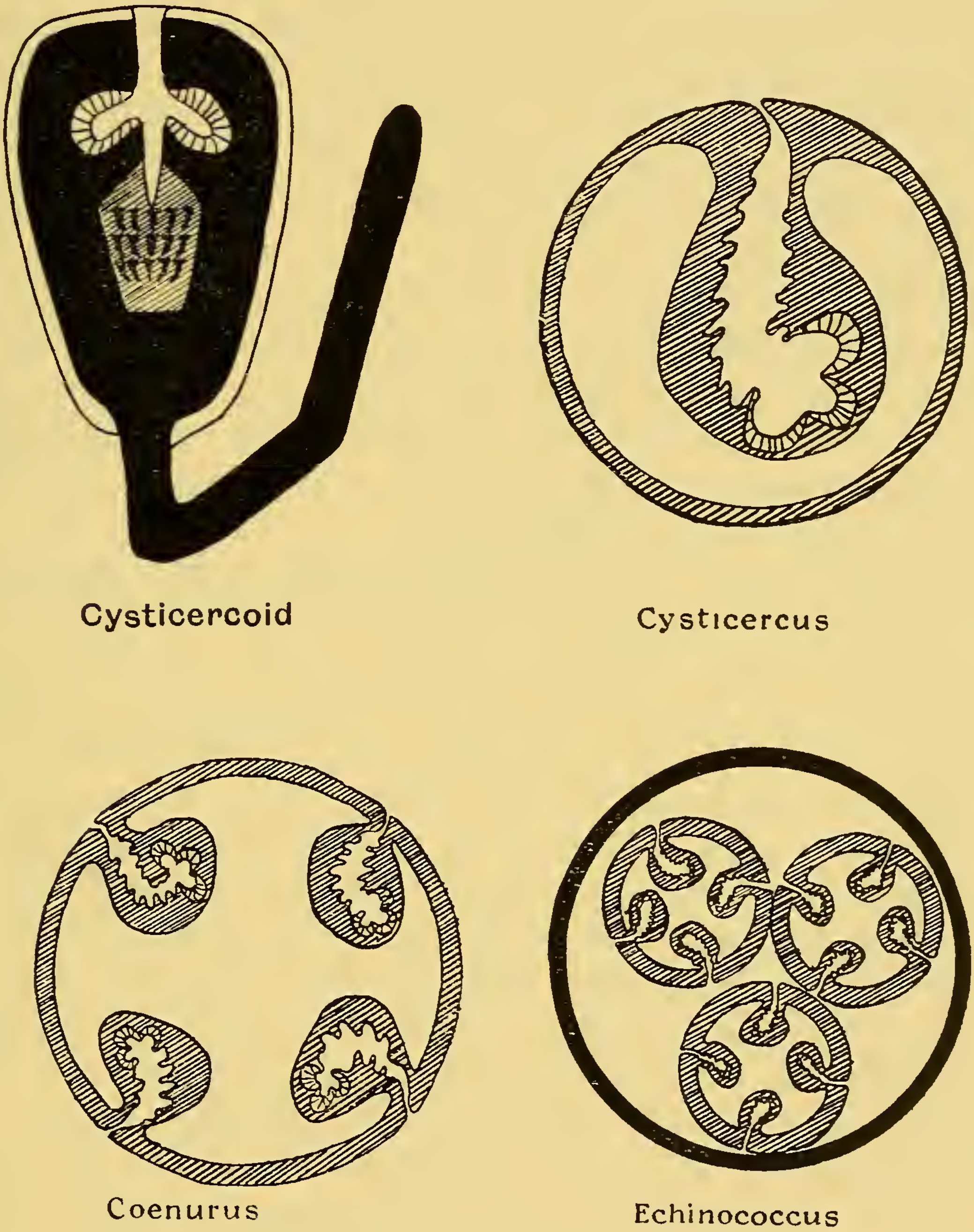



FIG. 15.—Types of Metacestode. (Not to scale.)

chiefly in the liver or lungs of various mammals, especially the sheep, ox, and pig, and its presence in man may cause very dangerous pathological conditions. The occurrence of this so-called "hydatid cyst" in man is common in Germany, Iceland, Paraguay, Argentina, and Australia; its favourite site is the liver (57 per cent. of cases), the lungs (8 per cent.), the kidneys (6 per cent.), and the spleen (3·8 per cent.). Infection

results probably from the eating of contaminated vegetables or salads.

Under the name of *Echinococcus multilocularis* there has been designated a sort of liver tumour of man which consists of numerous small cysts set side by side in honeycomb fashion ; a few of these cysts contain scolices. It is stated to be specifically distinct from the hydatid or unilocular echinococcus. This disease is nearly always fatal to man. The mountainous region of Southern Europe is the principal centre of distribution.

**Dipylidium caninum** is a common and widely distributed parasite of dogs, cats, and by infection from them, of children. The worm has a rhomboidally-shaped scolex, provided with a protrusible rostellum armed with three or four rings of hooks resembling rose thorns. The four adhesive cups are fairly large, oval, and shallow. The proglottids are easily recognised by their curved lateral edges, giving them the appearance of cucumber seeds, and by the presence of two genital openings, one on each margin ; there are in fact two sets of reproductive organs in each segment (Fig. 14).

The metacestode is of the cysticercoid type and occurs in the dog-louse (*Trichodectes*), the dog-flea (*Ctenocephalus canis*), and the human flea (*Pulex irritans*). The mature proglottids leave the anus of the mammal and wriggle about somewhat on the fur ; onchospheres, liberated by disintegration of the proglottis, are taken up by the louse or flea ; it is stated, however, that the eggs cannot pass up the suctorial tube of the adult flea, but are ingested readily by the flea larva. The eggs are said to hatch in the intestine of the flea larva, and the newly hatched metacestodes pass through the intestinal wall of the insect to the body cavity, where they remain through the further metamorphosis of the insect ; the dog or cat is infected by swallowing the insect parasite when licking its fur.

**Hymenolepis nana** is the smallest tapeworm occurring in man, rarely exceeding one and a half inches in length, although possessing about two hundred proglottids. The rostellum has four suckers and twenty-eight to thirty hooks (Fig. 14).

The small size of this tapeworm would seem to negative the possibility of injury being caused to the host, but actually such large numbers may coexist in the one host that serious intestinal irritation may result. In children particularly it causes considerable disturbance, diarrhœa and even epileptic symptoms.

It is morphologically indistinguishable from *Hymenolepis murina* of the rat and mouse, and by some authorities it is

regarded as synonymous with it. The geographical distribution of the parasite of man, however, does not appear to coincide with the distribution of the rodent form; the latter form is probably world wide in distribution, whereas heavy human infection with *Hymenolepis* is characteristic rather of sub-tropical and of tropical countries. In the Old World, for example, it is notoriously prevalent in the circum-Mediterranean countries and in tropical Asia and Africa. On the other hand, its presence in man is easily overlooked, unless the fæces are examined microscopically for eggs. Probably the more justifiable view is to regard the human parasite and the rodent parasite as biological races of the one species *Hymenolepis fraterna.*

The life-cycle is unknown. If it resembles that of *H. murina*, the metacestode stages may be expected to occur within the intestinal villi of the same host individual that harbours the strobila.

If the human tapeworm is identical with the rodent one, infection of man should occur through the contamination of human food by murine fæcal matter.

## CHAPTER VII

### HELMINTHES: The Roundworms

THE terms roundworm, threadworm, nematode worm, are applied to members of the zoological phylum, Nematelmia, certain free-living and parasitic organisms which, although sharply marked off from all other groups of worms, agree with one another very closely in appearance and structure.

As is the case with the internal parasites discussed in the preceding chapter, there are certain structural features, notably the smooth resistant cuticle and the absence of locomotor appendages which may be regarded as associated with the habit of endoparasitism. The fact that the alimentary canal, although simple, is developed and functional, and the occurrence of many more free-living genera than parasitic ones, would seem to suggest that the parasitic habit among roundworms is not of such long standing as is the case with flatworms.

They agree one with another in possessing those characteristics, such as the spindle shape of the body and the absence of definite head which are popularly associated with the term of "worm." The great majority are minute, even microscopic, and semi-transparent, but in certain families there occur forms large as the common earthworm, thickly cylindrical, with a white opaque body wall.

From the flatworms, they differ in having a cylindrical body. From the Annelida or segmented worms, they differ in the absence of segmentation, internally or externally; in the possession of a body cavity which is not a *cœlom*, that is to say is not homologous with the body cavity of annelid or of vertebrate; in possessing distinct sexes; and in not possessing a ventral chain of nerve ganglia.

The great majority of roundworms live saprobiotically in decaying organic matter, and these free-living forms are placed in the one family *Anguillulidæ*. The remaining families comprise semi-parasitic and parasitic forms.

The majority of endoparasitic forms live in the alimentary canal of other animals, but a number of forms are known to

inhabit the blood of animals, the connective tissues, the respiratory organs.

The variations in type of life-cycle can be illustrated best by description and discussion of certain forms which are of major economic interest.

**Ascarid Worms.**—The worms belonging to the family *Ascaridæ* are gut parasites of vertebrate animals, and may be described as somewhat long, thick, spindle-shaped forms, opaque dirty white in colour. The females are oviparous and the eggs usually possess a thick and sometimes sculptured shell.

The genus **Ascaris** itself occurs in most vertebrate animals. **Oxyuris** is a genus of small, curved, acutely pointed worms, usually termed "pinworms." **Heterakis** is a genus particularly prevalent in the cæcum of birds, and somewhat resembling small specimens of *Ascaris.*

**Belascaris** is an Ascarid characterised by wing-like projections from the anterior end.

**Ascaris lumbricoides** of man is morphologically indistinguishable from, and almost certainly a biological mutant from, *Ascaris suilla* of the pig.

*Ascaris ovis* of the sheep is believed to arise from chance infection with the eggs of either the man-*Ascaris* or the pig-*Ascaris*, and is said to be always sterile and incapable of reproduction. *Ascaris megalocephala* of the horse is, however, distinct from the human and porcine form.

Our knowledge as to the life-cycle of *Ascaris* is due in particular to the work of Ransome with *A. suilla* in the United States, the work of Stewart with *A. lumbricoides* in England, and the work of Yoshida with the same species in Japan.

The worm is found in groups of five or six in the upper part of the small intestine of the man or pig, and may easily pass into the stomach and be vomited therefrom. It is widely distributed, and the so-called "stomach worm" is very common in children, especially in tropical countries.

It is a large worm, thick as a lead pencil, the female averaging about ten inches in length, the male several inches less.

The eggs are ejected with the fæces of the host. They are oval, have a thick and warty but transparent shell, and when freshly passed are unsegmented. In damp earth or water they start to segment, and are fully developed in from ten days to a month. Under adverse conditions, however, they may remain dormant for years, being extraordinarily resistant to extremes of temperature or moisture, even to chemical disinfectants or to acids and alkalis.

Introduced into the host, generally by the medium of salads or unfiltered water, they hatch in the small intestine. The liberated larvæ penetrate the gut wall and are carried by the blood circulation to the liver or lungs. They may be found in the latter organs within a week of infection, and may provoke there mild bronchitis or even pneumonia. By the tenth day after initial infection they are 1-1·5 mm. long. They pass from the blood-vessels into the bronchial tubes of the lungs, thence through the trachea to the mouth, and are carried down to the small intestine where, in the appropriate host, they settle ; in an unsuitable host, such as a rat, they pass out with the fæces.

That Ascarid worms excrete a toxic substance seems certain. Most experimenters with *Ascaris* have noted considerable laryngeal irritation similar to that caused by formaldehyde vapour. An infected person may show peculiar mental and constitutional troubles, such as feverishness, anæmia, epilepsy, or delirium.

The life-cycle is thus a fairly simple one, only one host being concerned, and infection being contaminative, that is to say by the host swallowing the ripe eggs. A similar mode of infection characterises a large number of other nematode worms, parasitic in man and domesticated animals.

**Enterobius (Oxyuris) vermicularis,** the pinworm of man, lives as a young form in the small intestine ; as a mature adult in the cæcum and appendix. The eggs are, however, not laid in the parental habitat, but outside it, either in the host's rectum or even outside the anus in the groove between the buttocks or in the perineal folds of skin. It is the nocturnal migrations of ovipositing females which provoke the intolerable perineal itching characteristic of Oxyurid infection. The eggs measure 50-54 by 20-27 microns, are asymmetrically oval, and are laid at an advanced stage of development, so that if swallowed by the host they will hatch immediately. Auto-infection is possible and is probably very common.

The eggs are thin shelled and cannot withstand adverse conditions.

**Trichocephalus** is a genus comprising several morphologically different species, all found in the intestine of various mammals. *T. trichiurus* is the whipworm of man, one of the commonest human intestinal parasites.

It is a worm about two inches long, the anterior three-fifths being thread-like and buried between the epithelial folds of the cæcum. The characteristic dark-brown, lemon-shaped eggs,

with a plugged aperture at each end, occur in the fæces of the host, develop outside the host in moist soil and, like those of *Ascaris*, are extremely resistant to adverse conditions. They enter the host again in contaminated water or food.

All the forms described above have therefore a life-cycle that may be described as direct, infection of the host individual occurring through passive swallowing of the nematode egg and the egg hatching *within* the host.

It is possible that the typical life-cycle of a nematode worm comprises four larval stages between egg and adult stages, separated by moults. That is to say, there is the newly hatched or first stage larva, a second stage larva characterised by an enclosing "sheath," which is the loosened but unshed outer skin of the first stage, a third stage larva, a fourth stage larva, and then the adult stage.

In most cases of direct development the first stage is passed within the egg shell, the newly hatched larva being a second stage larva.

A second type of direct life-cycle is characterised by the hatching of the eggs *outside* the host, the presence of the first stage larva in moist soil, and its entrance into the host again as a second stage larva either by passive transference in food or water, or by active migration through the outer body surface of the host.

It is a type of life-cycle particularly characteristic of the family **Strongylidæ**.

The Strongylid worms are pre-eminently the most important of nematode parasites from a pathogenic standpoint, owing to the fact that they are in the main *tissue eaters*, actually rasping away the wall of their habitat and swallowing the comminuted tissue and blood.

They are readily distinguished from all other nematode worms by their mouth parts, which consist, generally speaking, of a number of thorn-like or hook-like teeth affixed to the inner wall of a horny cup which surrounds the mouth. They are therefore popularly termed "hookworms."

The male is characterised further by the possession of a membranous bell-shaped pouch, the so-called *copulatory bursa* which surrounds the cloaca and which is stiffened by ribs somewhat in the manner of an umbrella.

They are divided generally into **Lung Hookworms** (*Metastrongylinæ*), **Stomach Hookworms** (*Trichostrongylinæ*), and **Intestinal Hookworms** (*Strongylinæ*).

Sheep, and to a lesser extent cattle, pigs, and horses, often

harbour, in their lungs and tracheæ, hookworms of the genera *Dictyocaulus*, *Synthetocaulus*, and *Metastrongylus*. Lambs, in particular, may succumb in large numbers to the onset of pulmonary troubles, and concomitant anæmia and exhaustion, brought about by the presence in the windpipe and bronchioles of the " white lungworm " (*Dictyocaulus filaria*) and the " red threadworm " (*Synthetocaulus rufescens*).

The disease thus provoked is in Great Britain termed "hoose" or "husk." The white lungworms are numerous in the bronchioles, occurring in clusters of what look like four-inch pieces of white twine surrounded by a frothy mucus and lying in a swelling of the tube. Their presence causes the bronchitic symptoms.

The red worms occur in the lung cavities rather than in the bronchioles, and are much smaller, neither males nor females exceeding one and a half inches in length. Their presence provokes the pulmonary symptoms.

The life-cycle, as in the case also of other lung hookworms, is unknown. Dogs are peculiarly liable to lung trouble of a serious kind provoked by the presence of *Hæmostrongylus vasorum*, a pinkish threadworm some half to three-quarters of an inch in length, in the right ventricle of the heart and in the pulmonary arteries. The eggs of the worm become surrounded by a capsule of epithelial tissue, and these capsules may simulate in appearance the nodules of tuberculosis.

Stomach hookworms occur particularly in the abomasum or so-called " fourth stomach " of ruminants.

**Hæmonchus contortus,** for example, probably causes more loss among sheep than any other internal parasite. It is widespread in distribution, and is regarded with great disquietude not only by sheep farmers in Europe but by those of Argentina, North America, and North and South Africa.

The worms are small, half to three-quarters of an inch in length, so that thousands may occur in the abomasum of the sheep. The name *contortus* refers to the way in which the tubular white ovaries twist round the pink alimentary canal, as seen through the transparent body wall of the living worm.

The gastric strongylosis thus brought about is not characterised by specific symptoms. Affected sheep become weak and emaciated, show symptoms of anæmia and febrility, tend to shed wool, and just waste away. Whether the effects are due to mechanical abstraction of blood by the worms or to some toxin, is not certain.

Infection seems due to the eating of grass blades on which sheathed second stage larvæ of the worm are encysted.

The title of stomach hookworm is scarcely applicable to the Trichostrongylid species, *T. gracilis*, which lives in the cæca of the grouse (*Lagopus*). The worm is minute, less than half an inch in length, and the cæca of the grouse are unusually large, so that as many as ten thousand worms may occur in an infected bird. Their presence produces a chronic inflammation leading to fibrosis, the epithelial lining of the cæca becoming destroyed. Since these organs are probably the sole absorptory regions of the alimentary canal, the bird wastes away and dies. Deaths from "grouse disease" occur most commonly in the spring, when the birds are exhausted by a winter of semi-starvation.

The parasite is widespread, probably 95 per cent. of grouse on British moors being infected, and every heather tip of a grouse moor probably swarms with sheathed larvæ waiting to be ingested by a grouse. It would appear therefore impossible to prevent the infection of birds by this parasite.

The **Intestinal Hookworms** include several genera of very great medical and veterinary interest, notably *Ancylostoma*, *Necator*, *Strongylus*, *Œsophagostomum*, and *Syngamus*.

The genera **Ancylostoma** and **Necator** have come greatly into notoriety during recent years owing to the discovery of their pathogenic influence upon man.

**A. duodenale** and **N. americanus**, the two species concerned, are small worms, the male little more than one-third of an inch in length, the female a little longer than half an inch. As with hookworms generally, the males possess an umbrella-like copulatory bursa, and both sexes possess well-marked buccal capsules. The differences between the two species may be summarised as shown on p. 78.

These Strongylid species live in the small intestine of man, especially in the duodenum; they have been recorded also from anthropoid apes and have been successfully introduced into dogs. In other animals other species of these genera have been recorded, as well as species of the allied genera *Dochmius* and *Uncinaria*.

*Ancylostoma* and *Necator* do not seem to be true blood-suckers. Possibly they bruise the intestinal mucosa and accidentally take in blood, but their alimentary canal is not pigmented nor are their excreta black with melanin, as is the case with true bloodsucking worms.

There is no doubt, however, that they may give rise in the host to severe progressive anæmia, resulting in degeneration

of the heart, musculature, liver, and so forth, and accompanied by emaciation and dyspeptic trouble. Possibly these symptoms result from the production of hæmolytic toxins by certain glands in the head of the worm. In cases of long standing there is great retardation of mental and physical development. Children of twelve or fourteen years old are no farther advanced than children of half their age. The face has a bloated, stupid expression; the eyes have a characteristic hollow stare. A mania for eating earth or mud sometimes occurs.

| *Ancylostoma* | *Necator* |
|---|---|
| (1) Ventral margin of capsule with two pairs of curved teeth, the roots of which continue backwards and appear on the external surface of the capsule as rib-like thickenings. The dorsal margin has a gap in the middle, the rounded edge tips of which form the so-called "dorsal teeth." Inside the capsule are also two ventral, triangular lancets. | (1) Mouth capsule narrow and without teeth, merely possessing a thickening of the ventral edge of the capsule. There is, however, a chitinous cutting plate on each side. A pair of ventral lancets present. |
| (2) Genital aperture of female in posterior half of body. | (2) Genital aperture of female in anterior half of body. |
| (3) Posterior tip of female with a fine spine. | (3) Female without posterior spine. |
| (4) In the male, the rib supporting the dorso-median lobe of the bursa forks about half-way up from its base, and each branch divides into three. | (4) In the male, the rib supporting the dorso-median lobe of the bursa forks near its base, and each branch divides into two. |
| (5) If the worm be slowly killed, the head lies in the same plane of curvature as the body. | (5) If the worm be slowly killed, the head is curved in a plane different to that of the body, so as to give a hook-like effect. |
| (6) A similar curvature occurs with the bursa of the male. | (6) A similar curvature occurs with the bursa of the male. |
| (7) Mean dimensions of eggs are 60 by 40 microns. | (7) Mean dimensions of eggs are 70 by 40 microns. |

There can be little doubt that the endemic presence of hookworms among large populations results in tremendous loss of efficiency and greatly retards the progress of education. The marked inferiority of tropical labour as compared with temperate zone labour can be ascribed almost entirely to the destructive influence of years of hookworm disease and malaria upon racial stamina.

**The Distribution and Prophylaxis of Hookworm Disease.**—*Ancylostoma* and *Necator* occur, one or the other, almost everywhere between latitude 52° N. and 30° S. In Egypt, where nearly every native is infected, the disease has existed since earliest times; it may be ancylostomiasis that is referred to

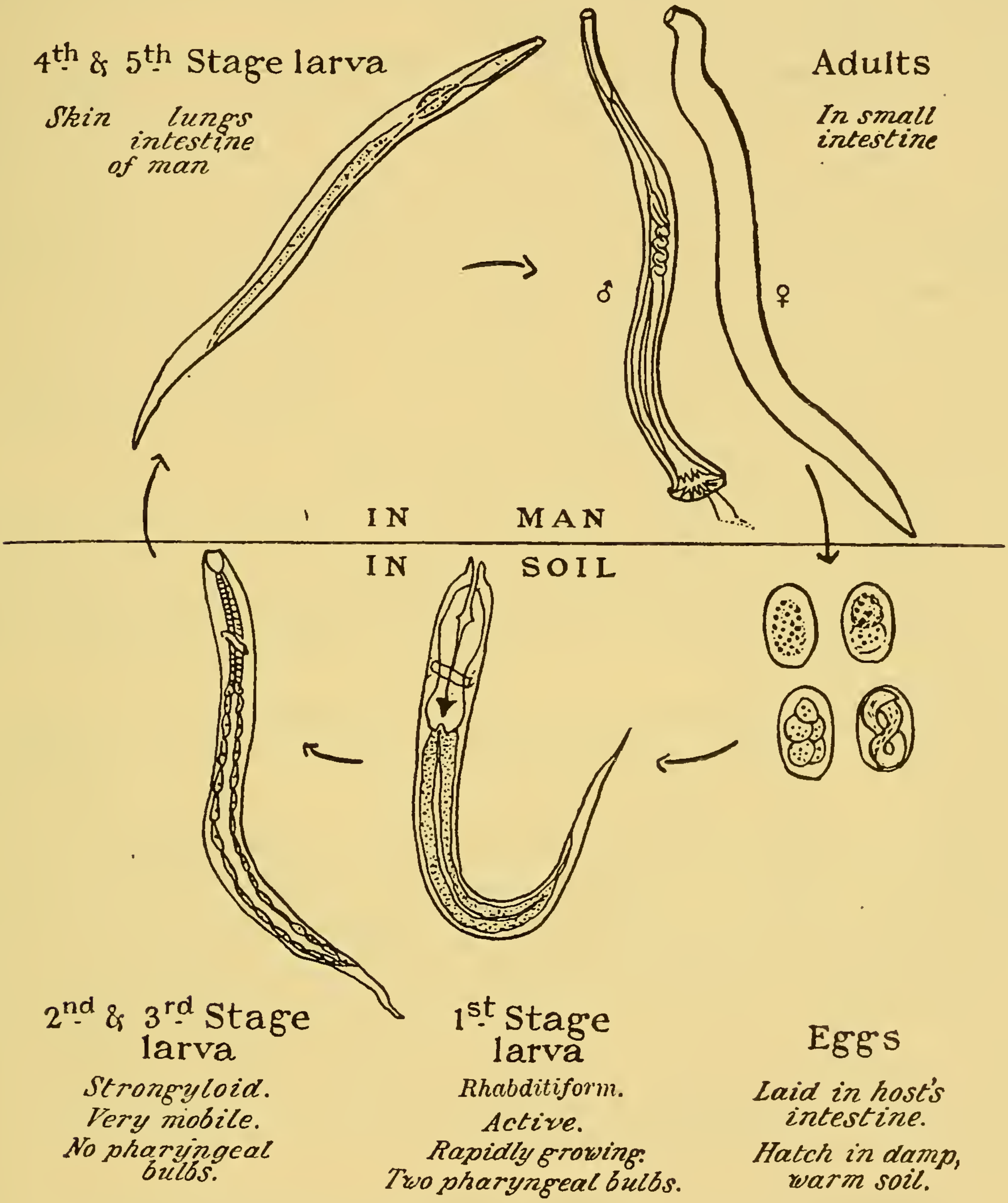



FIG. 16.—Life-Cycle Stages of *Ancylostoma*. (Not to scale.)

in the Ebers papyrus of 1550 B.C. It is equally common in India, Eastern Asia generally, and occurs in Europe and in America.

*Necator* has accompanied the African negro to South and North America, the West Indies, and the Pacific Islands. *Ancylostoma* may have spread from the Mediterranean area to Asia, Africa, and America.

Both genera are extremely widespread in these areas, and

their extent of distribution is limited only by conditions of soil temperature. Outside the latitudes given above, the hookworm can only establish itself under the conditions afforded by the interiors of mines and tunnels. It gained admittance, for example, to the Cornish tin mines in 1902, introduced probably from the Transvaal, and it was prevalent in the Simplon tunnel during construction.

As the success of preventive and eradicatory measures, when applied to an endemic disease, depends so very greatly upon accurate and simple diagnosis and upon detailed knowledge of the life-cycle of the causative organism, it is particularly fortunate that our knowledge of the hookworm is so thorough.

The pathological effects produced by hookworms are not so clear cut as to enable the presence of these parasites to be determined from them with certainty. Fortunately, however, unfailing and certain indication of hookworm infection is afforded by the characteristics of the eggs.

The thin-shelled eggs commence to segment whilst in the host intestine, and when observed in the fæces are usually in the two, four, or eight-cell stage. This segmentation and their transparency distinguishes them from the eggs of other intestinal helminthes (Fig. 17).

Further development requires exposure to oxygen, a moderately high temperature of 65°-80° F., and the presence of moisture. The newly hatched larva is about 0·2 mm. long, has a bottle-shaped œsophagus, a simple gut, and no reproductive organs. If the habitat be moist and well aerated, and if plenty of decomposing organic matter be present as food, this larva feeds and grows rapidly until it is 0·5 mm. long by the end of five days. Then the cuticle separates but remains as a sheath around the larva, which is now ready to enter the human host. Feeding stops, and the larva wanders actively through the moist substratum.

Entrance into the host is gained by boring through the skin of the legs, probably down a hair follicle, and entering a vein, whence they pass via heart, lungs, œsophagus, and stomach to the intestine. Two moults are passed through whilst wandering in the host, and four to five weeks are required in the host before maturity is reached (Fig. 16).

A campaign against hookworm therefore must comprise :—

(1) Measures for the expulsion of the worms from infected persons.

(2) Measures to prevent contamination of soil by the fæces of infected persons.

(3) Measures to prevent the passage of active larvæ into the human host.

(4) Extensive educational propaganda.

The first measure is effectively carried out by the establishment of travelling clinics where people can be examined and treated free of charge. It must be remembered that it is the extremely poor and illiterate sections of a population that are most subject to the disease. Thymol was until recently the classic drug for hookworm, but its use is rapidly becoming supplanted by that of oil of chenopodium.

The second measure requires the establishment of an efficient system of latrinage and of sewage disposal. In most tropical countries among the people where hookworm disease is rife, latrines are, as a rule, unknown, so that the surface soil around habitations may teem with hookworm larvæ. Contaminated ground can, of course, be treated with disinfectants or with salt, but large quantities are required.

The third measure is carried out by the encouragement of the wearing of boots or shoes by field workers, or where people habitually do not use foot-gear, or are too poverty stricken to acquire them, by encouragement of the habit of smearing feet and legs with some form of tar.

Educational propaganda comprises an extensive campaign of lectures, free illustrated pamphlets, posters, and school instruction.

Acting on such lines, the American International Health Board, financed munificently by John D. Rockefeller, has carried out an enormous amount of valuable work since 1909 in the eradication of hookworm disease not in the United States alone, but in South America, Egypt, the West Indies, Eastern Asia, and elsewhere.

A great many other intestinal hookworms have been reported from the alimentary canal of horses and cattle and, occasionally, of man.

**Strongylus equinus,** for example, is, after *Ascaris*, the commonest nematode parasite of the horse, and certainly the most injurious. Its position in the host is curious. Coupled males and females occur in the cæcum. Larval or immature stages occur in many of the arteries, in the portal vein, the liver, pancreas, lungs, testes, and in submucosal swellings of the cæcum, varying from a pinhead to a nut in size.

The worm measures three-quarters to two inches in length, is straight in shape, greyish-brown in colour, and has a buccal capsule provided with two cutting plates.

The eggs, expelled with the fæcal matter, develop in water or damp earth, and hatch within eight days. The larvæ reach the small intestine of the host in drinking water. From there they wander into the circulatory system, but eventually they encyst in the submucosa of the cæcum and complete their development until provided with buccal capsule and caudal bursa. Finally they pass into the cavity of the cæcum through an aperture in the cyst, become mature and copulate.

The adult worms in the cæcum, despite their number and blood-sucking propensities, probably provoke no serious trouble beyond diarrhœa and emaciation. The larvæ, however, in the circulatory system may cause serious aneurisms, especially on the mesenteric arteries, aneurisms as large as a walnut, and containing up to a dozen pink larvæ. Or they may cause obstruction of the blood-vessels. Animals infected by the armed strongylid are prone to attacks of colic.

The genus *Syngamus* is more particularly a nematode of birds.

**Syngamus trachealis,** for example, is a serious parasite of young Galliform birds. The worms occur in large numbers attached to the inner lining of the windpipe of infected birds, especially where the pipe divides into the bronchioles. Each worm looks like a tiny letter Y ; one of the small arms of the Y represents the male, the rest of the Y representing the female ; they are permanently and inseparably coupled. In spite of the permanent copulation, eggs can pass from the vagina of the female into the bursa of the male, and are then ejected forcibly from beneath the dorsal flap of this bursa.

The eggs, as seen in the fæces of infected birds, never show development beyond the sixteen-cell stage. They are somewhat different from other strongylid eggs, being oval and having each extremity thickened to form a little cap.

These eggs take about a week to develop and to produce infective larvæ. A somewhat high temperature, namely 25° C., is required, but apparently the unhatched egg may also be infective. The contained embryo moults before hatching, so that the larva which actually emerges is really a second stage larva, surrounded by a sheath, and thus not very active. It reaches the bird almost certainly by being picked up and swallowed, although possibly the earthworm may serve as a mechanical intermediate host. From the alimentary canal of the bird, the larvæ in some way, not yet with certainty determined, reach the lungs, and in so doing lose their sheath. In the alveoli of the lungs these larvæ develop further. Then

they migrate to the trachea, copulate, and attain sexual maturity. The whole life-cycle occupies a month. The effect of these parasites upon a bird is, briefly, to asphyxiate it, an effect produced not only by their numbers but by the copious secretion of mucus induced by their presence. Badly infected chicks run about with beaks widely open, and hence the disease is termed "gapes" in English-speaking countries. Enormous losses are caused among young poultry and pheasants by this disease.

Several remedies have been tried with success. Birds may be shut up in a box and a fog of camphorated chalk produced by the aid of a bellows to induce the birds to cough vigorously. Another remedy which has given excellent results is the injection of 1 c.c. of 5 per cent. sodium salicylate solution into the trachea through a hypodermic syringe. Prophylaxis comprises the isolation of infected birds, removal of non-infected birds to a fresh site, and treatment of the soil of the old runs with salt solution or with a 1 in 1,000 solution of sulphuric acid.

A link between the type of life-cycle characteristic of Strongylid worms and the type seen in the case of Ascarid worms is afforded by the genus **Strongyloides.**

*S. stercoralis* is a very small worm, about one-tenth of an inch long, which bores into the intestinal mucosa of man. Only the female is known, and she is recognisable by the chain of six or seven eggs lying near the middle of the body and visible through the transparent body wall. The eggs are laid deep in the intestinal mucosa and hatch there, so that the first stage larvæ occur in the fæces. They may be mistaken, sometimes, for newly hatched hookworm larvæ in fæces which have been kept for more than a day before examination, but the larva of *Strongyloides* is long and slender and easily distinguished from the *Ancylostoma* larva by the fact that its long, slender œsophagus extends nearly to the middle of the body. Further development of the larvæ requires water of somewhat high temperature. Under such conditions the larva becomes an adult, either male or female, very different from the intestinal form. These copulate, and the females lay thirty or forty eggs within two days. These eggs produce larvæ similar in form to their free-living parents, but after a moult, similar to the gut-living grandparent. This larval type penetrates the body surface of a human host much as the hookworm larva does, mainly through the hair follicles.

A third main type of life-cycle is characterised by the eggs hatching in the parental uterus by the liberation of living larvæ within the body of the host, and by the transference of the larval

stages to another host individual by the intermediate aid of another type of animal. That is to say, in this case the life-cycle is an indirect one and comprises a primary or definitive host and a secondary or intermediate one.

The simplest example of this type of life-cycle is afforded by the case of the genus

**Trichinella.**—This nematode lives in the adult condition in the small intestine of man, the rat, the pig, and occasionally in other domesticated animals. Rats are more easily infected than sheep or horses, and the latter are more easily than cats or dogs. All these animals also serve as intermediate hosts.

The worms are small and live between the intestinal villi or even within the crypts of Lieberkühn. After copulation the males die, but the females increase as much again in size and bore through the mucosa into the lymphatic spaces. Here living larvæ are extruded, and these become carried passively by the lymph stream to the heart, and from thence to various parts of the body.

Only such larvæ, however, as arrive in muscular tissue can survive. Particularly do they seem to arrive in the muscles of diaphragm, ribs, neck, throat, and eye, that is to say, in muscles whose blood supply is rich and where there is a high oxygen content and a high glycogen content.

Ten days after initial infection these muscles of the host will contain innumerable lemon-shaped cysts lying among, and parallel to, the muscle fibres, and each containing a larval *Trichinella*, coiled in a loose spiral and living apparently upon the glycogen of the muscle. The cyst wall appears to be an inflammation product of the connective tissue, rather than a secretion from the worm itself.

Incredible numbers of such cysts may occur, as many as two millions in a pound of infected sausage meat having been recorded.

The cyst wall is usually calcified, and the cyst may remain potentially infective for years. If swallowed, however, by an appropriate host, the encysted worms emerge, and within forty-eight hours are copulating.

Pigs become infected by eating dead rats. Man becomes infected by eating undercooked and infected pork. In France and Great Britain the disease of trichinosis is rare, but in Germany and North America the custom of eating raw or smoked ham or sausage has been responsible for many epidemics. The parasite may have come from the East with the grey rat at the end of the eighteenth century.

Invasion of the muscles in man produces muscular tenderness or even interference with the respiratory or œsophageal functions, accompanied by much swelling of face and eyelids. Lung trouble and death are common sequelæ, the mortality in an epidemic being sometimes as high as 30 per cent.

Prophylactic measures are two, namely :—

(1) The extermination of rats in the vicinities of piggeries and abattoirs.

(2) The avoidance of pork which has not been subjected to a temperature *throughout* of 62°-70° C.

Cold storage for twenty days below 5° C. is effective in sterilising the meat, according to the Regulations of the United States Bureau of Animal Industry.

The most complete example of nematode worms with distinct primary and secondary hosts is afforded by the members of the family **Filariidæ**, a family of very long, slender worms whose members occur in the lymphatic vessels, heart, serous cavities, or the subcutaneous tissues of vertebrate animals, and whose larval stages occur in the circulatory system and are carried from host to host by a blood-sucking arthropod. The best known genera are *Filaria*, *Dracunculus*, and *Onchocercus*. **Filaria bancrofti** occurs in the form of a hair-like female two to six inches long, coiled round a slender male about half the size, in clumps in the lymphatic glands and ducts of man in tropical and sub-tropical countries.

Obstruction of the lymphatic system by clumps of these worms provokes certain pathological lesions, in particular an enormous enlargement of the part of the body where the obstruction occurs, referred to as "elephantiasis." Such elephantiasis affects particularly the lower limbs and scrotum. The disease is characterised by repeated attacks of filarial fever or lymphangitis, in which chills and high fever accompany a painful swelling of the part affected. After each attack has subsided, a hard layer of permanent tissue is left, and so the hard, unyielding growth is gradually built up. Escape of the contents of lymph vessels into the kidneys or bladder produces chyluria, or the presence of a milky, coagulable condition of the urine.

The embryos or microfilariæ occur in the peripheral blood circulation, and were known long before their connection with the adult filariæ was suspected, under the name of *Filaria sanguinis hominis*. They were found to occur always in the blood of persons suffering from chyluria, elephantiasis, and lymphatic tumours as minute, wriggling, eel-like creatures enveloped in a sort of sheath somewhat longer than the body.

It has long been known that these forms are present in the peripheral blood during the night and absent during the day, retiring then, as indicated by post-mortem examinations, to the capillary vessels of the lungs and heart and to the larger arteries. No satisfactory explanation of this phenomenon has yet been put forward, and the difficulty of framing a physiological explanation which will fit the facts is made greater by the fact that in Fiji, the Philippine Islands, and the South Sea Islands the embryos of *Filaria bancrofti* do not show this periodicity, and that the very closely related *Loa loa* has microfilariæ whose appearance in the peripheral blood is diurnal.

It is certain that this appearance of the embryonic filariæ in the peripheral blood is correlated with the use of the mosquito as an intermediate host. A large number of mosquito species are known to serve as intermediate hosts, but only in four or five has the complete development been observed, namely, in *Culex pipiens*, *Culex fatiguans*, *Stegomyia pseudoscutellans* among Culicines, and *Myzomyia rossii* and *Pyretophorus costalis* among Anophelines.

In the mosquito the embryos pass into the stomach, and each gradually works its way out of the containing sheath. The liberated larval stage then makes its way between the fibres of the thoracic muscles and remains there for a time, growing rapidly, developing a mouth and alimentary canal, and becoming thicker and longer. Eventually it leaves the muscles and passes into the proboscis of the insect, into the cavity of the labium, in fact, whose thin enveloping cuticle it punctures so as to arrive between the piercing mouth parts.

When the mosquito bites man, the filariæ are deposited on the skin in the vicinity of the puncture and are said to penetrate the epidermis and reach the subcutaneous tissue, from there to migrate to the lymphatic vessels, where they become sexually mature and copulate.

**Loa loa** is a form very similar in appearance to *Filaria bancrofti*, but characterised by possessing a cuticle studded with small excrescences. It is native to West Africa, particularly to the Congo region, but has been introduced by the slave trade into South America, where, however, it is now somewhat rare.

The adult worm lives in the subcutaneous tissues and is very active, creeping along at the rate of about an inch in two minutes just below the skin, especially if the skin be warmed.

When in deeper tissue the presence of the filariæ provokes painful temporary swellings, the so-called "Calabar swellings."

The microfilariæ occur in the peripheral blood by day and not by night, so that the possibility of a mosquito serving as intermediate host seems doubtful. There is some evidence that Tabanid flies, of the genus *Chrysops*, may serve as intermediate hosts.

**Filaria immitis,** the "cruel worm" of dogs, inhabits the right ventricle and pulmonary artery of dogs and other carnivores. The female is viviparous, and the larvæ remain in the blood until taken up by a mosquito. Since the parasite is cosmopolitan in distribution, various species of mosquitoes may transmit it; in Europe, *Anopheles maculipennis* and *Anopheles bifurcatus* are concerned; in Australia and North America the carrier is *Culex fatiguans*.

Infection is said to be fatal to 50 per cent. of mosquitoes owing to destruction of the Malpighian tubules by larvæ which have penetrated the wall of the midgut. The disease is fatal to the vertebrate host owing to destruction of the red blood corpuscles.

The close related *Filaria recondita* of dogs is transmitted by the dog-flea and a tick, *Rhipicephalus siculus*.

A new species of *Filaria* described by Theiler in South Africa, namely *Filaria gallinarum*, has for intermediate host not a blood-sucking insect but a termite, *Hodotermes pretoriensis*. Worker termites, it is believed, swallow the eggs, and the larvæ undergo development in the cœlomic cavity of the insect, and complete it in the fowl.

The genus *Dranunculus* of Filariid worms is peculiar in that, according to some authors, no genital aperture exists in the female, and the eggs escape from the body via the mouth. Other authorities state, however, that an aperture exists just behind the cephalic shield.

**Dracunculus medinensis** is an extremely long, slender worm, sometimes as long as three feet, which lives in subcutaneous ulcers of man, especially located on the ankles, on the legs, and backs of water carriers, on the arms of native women. Originally African and particularly distributed in the Sudan, West Africa, and Arabia, it has become introduced into tropical America. It has been known since remote times, and is undoubtedly the prototype of the "fiery serpents" which afflicted the Israelites during the wanderings. The common native method of extracting the adult worm by coiling the protruding end around a stick and winding the creature out has probably led to the association of the rod of Æsculapius with the twining serpent, familiar as the badge of the British Royal Army Medical Corps.

When mature, that is to say about twelve months after the initial infection, the worm approaches the skin surface, so that its head lies just below the cuticle. Owing probably to the discharge of some irritant fluid, a blister large as a florin forms above the site of the worm. After a day or two this blister bursts and forms an intensely painful ulcer, from the bottom of which the head of the worm protrudes. If the ulcer comes in contact with water, a milky fluid is discharged from a little bladder near the mouth, representing probably the prolapsed extremity of the uterus. This fluid swarms with tiny coiled larvæ having characteristically straight tails.

The resemblance of these larvæ to those of the Strongylid *Cucullanus*, a blood-sucking Nematode parasite of the perch, whose larvæ develop in the water flea *Cyclops*, led Leuckart to suspect a similar intermediate host for *Dracunculus*, and the work of Fedschenko, Leiper, and others has since fully substantiated this suggestion.

The larvæ enter a species of *Cyclops* by penetrating the exoskeleton, or, according to Leiper, by entering the mouth, and encyst in the body cavity. Experiment shows that slight acidity of the medium, such as is provided by the hydrochloric acid of the human stomach, kills the *Cyclops* but stimulates emergence of the Nematode larvæ, so that man is probably infected by swallowing *Cyclops* individuals.

The native method of extracting the worm is that of rolling the protruded portion around a stick an inch or two per day until fully withdrawn. The method is dangerous, since if the worm be broken, larvæ will escape into the subcutaneous tissues and cause severe inflammation and abscess formation. More satisfactory is the method of securing the worm by a ligature and injecting into it a solution of 1 in 1,000 corrosive sublimate or of chloroform. Extraction is then usually easy after a few hours.

Prophylaxis consists in the avoidance of unfiltered or unboiled water in regions where the worm is endemic.

Closely related to the Filariæ is **Onchocerca,** a slender worm several inches long and slender as a hair, which occur in couples in subcutaneous fibrous tumours, the so-called "onchocerca nodules" in men and animals. The tumour varies in size from a nut to a pigeon egg and, in addition to several pairs of adult worms, contains small spaces swarming with sheathless microfilariæ. These are believed to migrate into the peripheral blood and to be taken up by blood-sucking flies.

*Onchocerca volvulus* affects man in West and Central Africa.

*Onchocerca gibsonii* affects cattle in Australia.

## CHAPTER VIII

### HELMINTHES : The Pathological Aspect

It will be apparent from the preceding chapters that there are few places in the animal body that are not liable to become the site of infestation by some form of helminth parasite.

Certain organs, however, are more likely than others to harbour a wide range of such parasites.

The vertebrate alimentary canal is one such organ ; in the stomach occur particularly many Strongylid and Filariid worms ; in the blood-vessels and ducts of the liver occur such flukes as *Distomum*, *Fasciola*, *Dicrocœlium*, *Opistorchis*, *Clonorchis*, *Schistosoma*, and the liver substance, or the connective tissue in proximity to it, is a favourite site for metacestode stages of tapeworms ; in the intestine occur such flukes as *Heterophyes*, *Echinostomum*, *Holostomum*, *Amphistomum*, the strobila stage of tapeworms, Ascarid worms, Strongylid worms, Trichinellid worms, Echinorhynchid worms, and so forth. The outer skin and the invaginated epithelium which lines buccal cavity, rectum, and even the bladder are liable to afford a habitat for ectoparasitic flukes.

Lungs and trachea may harbour such forms as *Paragonimus*, *Metastrongylus*, *Dictyocaulus*, *Hæmonchus*, *Syngamus*, and so on.

Muscles and subcutaneous tissue may be attacked by metacestode stages of tapeworms, by Filariid worms, by Trichinellid worms.

The circulatory system may contain species of *Schistosoma*, *Bilharziella*, and microfilariid larvæ.

The question of the general effect of helminth parasites upon the well-being of the host is therefore a wide one.

Speaking very generally from the pathological standpoint, the presence of helminth parasites—

(*a*) May apparently cause no inconvenience at all to the host.

(*b*) May cause general malaise.

(*c*) May cause definite localised lesions recognisable as associated with particular parasites.

It is somewhat dangerous to assume that any helminth parasite is neutral to its host. Our ignorance of the pathology of animals other than man and domesticated animals is so profound, and our knowledge of the details of the life history of even common helminth parasites so full of gaps, that many parasitic forms regarded to-day as harmless to their host may be shown by fuller investigation to be of very great pathological importance. In the past, helminth investigation has been wedded so closely to tropical medicine that the pathological importance of parasitic worms to the inhabitants of temperate latitudes has been to some extent neglected.

Concerning the pathogenic aspect of *Schistosoma*, *Ancylostomum*, *Filaria*, the literature is voluminous ; concerning the pathogenic aspect of the much more common nematode genera, *Oxyuris*, *Ascaris*, and *Trichocephalus*, knowledge is scanty. Yet the numerous observations recorded of the frequent association of *Oxyuris vermicularis* of man with many conditions clinically recognised as appendicitis, justify a more thorough investigation of the subject ; the probable identification of the human and the hog forms of *Ascaris* and the occurrence in both hog and man of bronchitic trouble caused by migrating larvæ of *Ascaris* certainly justify an inquiry as to whether it may not be the provoking agent of diseases regarded as obscure and indefinite.

The term **helminthiasis** is usually applied to a group of symptoms including particularly severe anæmia, malnutrition, mental and physical retardation, vomiting, diarrhœa, bronchitis, pulmonary disturbance, febrility, when associated with the presence, in fæces or sputum, of eggs or larval or even adult stages of helminthes. Where the causative helminth is known, the group symptoms may be termed ascaridiasis, strongyliasis, ankylostomiasis, filariasis, and so on. The symptoms arise indirectly through the presence of the parasite, through its propensity for absorbing the intestinal juices or the blood of its host, or through its excretion of toxic products into the system of the host.

Definite tissue lesions may be produced in several ways ; intestinal helminths may dissolve away the mucous epithelium, may actually puncture it, or may break right through into the submucosa ; in either way they permit secondary bacterial infection to occur, and so indirectly pave the way for appendicitis, enteritis, peritonitis, or even typhoid fever.

Again, the mechanical pressure of a large parasite, such as, for example, a metacestode cyst, upon such an organ as the

brain, the nerve cord, the liver, or the lung, may cause serious disturbance in the host. The active migration of larval stages of helminthes through host tissues may provoke lesions. The accumulation of large numbers of parasites in capillary blood-vessels or lymph-vessels, in bile-bucts or pancreatic ducts, or in trachea or bronchioles, may be of the utmost pathological importance to the host.

**The Diagnosis of Helminth Parasites.**—The problems of helminthology depend for successful solution upon (*a*) accurate knowledge of the life-cycle ; (*b*) accurate methods of diagnosing the presence of helminthes in the host. The accurate study of a helminth life-cycle demands a highly trained laboratory worker, and necessitates :—

(1) A knowledge of the precise morphology of the adult parasite, its larval stages, its diagnostic differences from related forms.

(2) Ample sources of material of all stages.

(3) The elaboration of methods of host examination, of parasite cultivation outside the host, of experimental infection of uninfected hosts, and so on.

The clinical diagnosis of the prevalence of helminthes within an animal depends :—

(1) If the animal be alive, largely upon the discovery and identification of eggs, or more rarely of living worms, in the fæces, urine, sputum, or blood of the animal.

(2) If the animal be dead, upon the discovery and identification of adult worms in the alimentary canal, respiratory tract, muscles, or connective tissue.

Certain precise and standard methods for the examination of eggs and worms in fæces or animal secretions are now in general use, and accuracy of technique is most important. There are at least four methods that can be used. Each has its advantages and disadvantages as compared with the others. They are : (1) the Smear Method ; (2) the Centrifugation Method ; (3) the Brine Flotation Method ; (4) the Culture Method.

The **Smear Method** is simple, quick, applicable to any suspected body fluid, and affords information as to the presence of protozoal organisms as well as of helminthes. On the other hand, it is not to be relied upon in the case of light infestations. It is carried out by taking a small quantity of the fluid under examination and smearing it over the surface of a glass slide so that it can be examined microscopically. The smear should be sufficiently thin to enable

print to be read through it. Fæces or thick sputum, therefore, should be first emulsified with a little distilled water.

The **Centrifugation Method** is applicable to fæces or to urine. A piece of fæces large as a walnut is emulsified with distilled water, filtered through a coarse sieve into a tube which is corked at each end, and then centrifugalised. The sediment is allowed to settle on one or other of the corks, and can then be removed, smeared over a slide, and examined.

The **Brine Flotation Method** depends upon the greater density of brine over that of some helminth eggs. A piece of fæcal matter should be emulsified with equal parts of glycerine and saturated salt solution, the floating matter forced below the surface with a disc of steel wool, and allowed to remain for an hour. The surface film is then removed with a loop of platinum wire on to a glass slide and examined without a cover glass.

It must be noted that this method will not indicate the presence of operculate eggs, such as those of flukes or of bothriocephalid tapeworms, nor, as a rule, does it indicate the presence of nematode larvæ. A precise application of this method, used in the diagnosis of *Ankylostoma* infection, is as follows: The emulsified fæcal material is centrifugalised with distilled water. The supernatant fluid, containing food débris, is poured off. To the sediment, calcium chloride solution of sp. gr. 1·050 is added. The fluid is again centrifugalised and decanted. Then calcium chloride solution of sp. gr. 1·250 is added and the fluid centrifugalised. The hookworm eggs then float on the surface of the fluid.

**Cultivation Methods** are, generally speaking, applicable to nematode worms only, and they have the disadvantage of taking up too much time to be useful as routine methods. They are, however, much more certain in their results, and will afford evidence of infestations that other methods may overlook.

The fæcal sample is mixed with bone black, or with sterilised sand or humus, and spread out over a quarter inch pile of circular filter papers in a shallow dish to the depth of one inch. The surface is kept moist and the culture is incubated for five or six days at 25°-30° C. Then the culture is flooded with water which is then decanted, centrifugalised, and examined.

Even after a good smear has been obtained, the identification of helminth stages which may occur in it is not an easy task.

Usually the clear-cut outline of the eggs or of the animals themselves helps to distinguish them from the various vegetable cells, soaps, crystals, leucocytes, and other miscellaneous fæcal

débris, but such distinction is not always readily made; undigested banana fibres, for example, resemble astonishingly

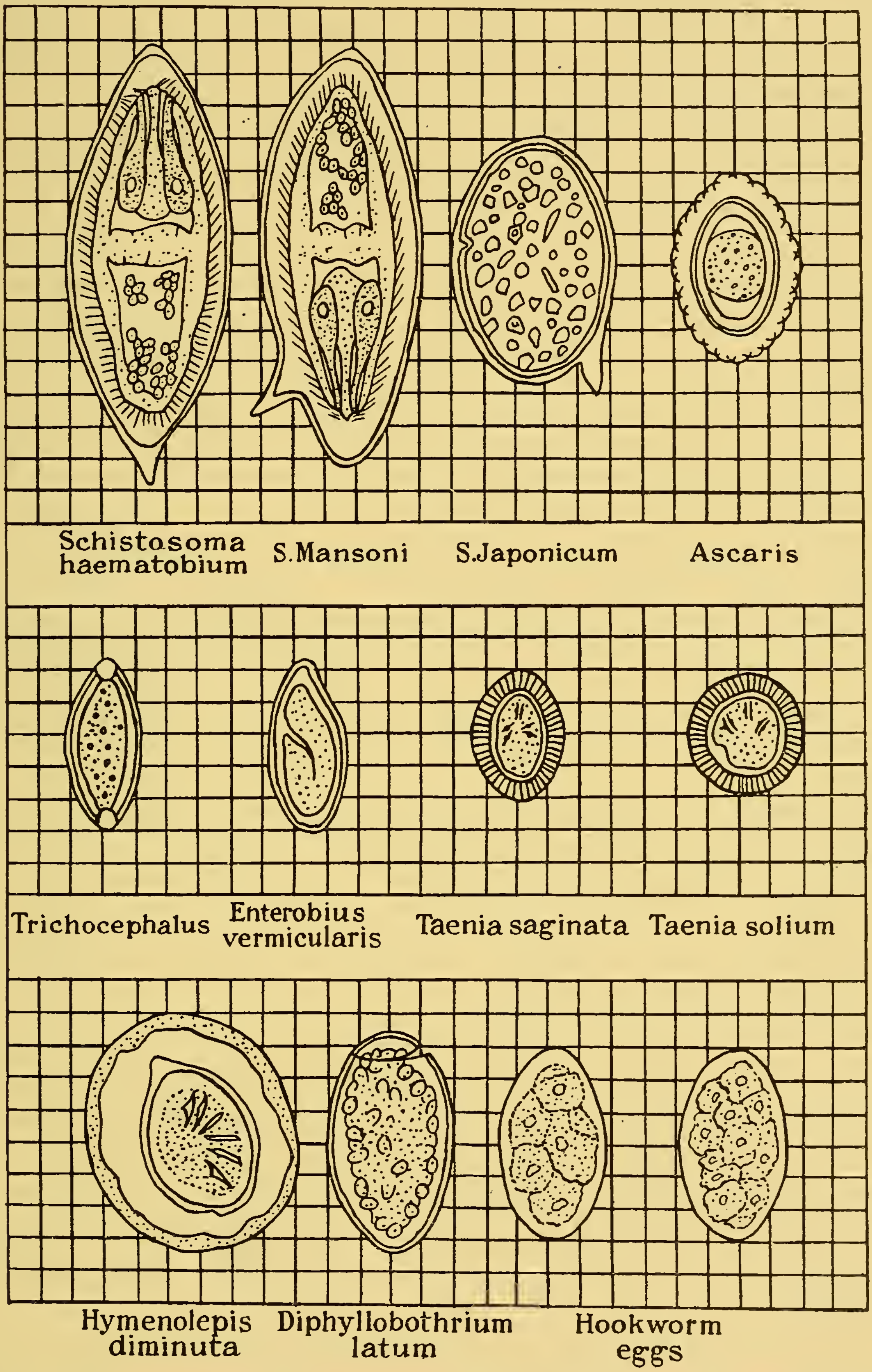



FIG. 17.—Helminth Eggs occurring in Human Fæces. (After various Authors.)

a cluster of small tapeworms; starch grains or crystals may be readily mistaken for eggs or for protozoan cysts.

The possession of an operculum or lid by an helminth egg relegates it to some species of fluke or of bothriocephalid tapeworm ; the presence within it, of a six-hooked embryo, indicates that it is the egg of a tæniid type of tapeworm. Nematode eggs are thus fairly easily distinguished from those of flatworms.

Further identification of an egg depends upon :—

(*a*) Its long and short diameter, expressed in microns.

(*b*) The nature of the external shell, whether thick and sculptured, or thin and transparent.

(*c*) The stage of development of the eggs, whether unsegmented, or four-celled, or many celled, or even embryonic.

Fig. 17 indicates the general size and appearance of the commoner type of helminth eggs. Identification of the larval or adult worm depends upon various structural characters.

In adult Trematoda the identification rests upon the number and position of the suckers and the arrangement and shape of the reproductive system components.

Adult tapeworms are identified upon characters of the suckers, the number, arrangement, and shape of the hooks on the rostellum, the shape of mature proglottids, the arrangement of the genital pores, and the shape of the ripe uterus.

Metacestode stages of tapeworms are identified by the character and arrangement of the suckers and the rostellar hooks.

Nematode worms are identified principally from the nature of the following structural features :—

(1) The shape, whether short and thick, or slender and thread-like.

(2) The mouth aperture, whether consisting of lips, true jaws, or of a capsule or cup.

True lips consist usually of three labial projections surrounding the mouth. The largest of the three represents probably a fusion of two, and occupies the entire dorsal half of the oral aperture. The two smaller lips are ventral and separated by a narrow median slit. These lips can grasp and draw between them small objects. Usually the three-lipped condition is associated with an œsophagus whose lumen is triradiate.

Jaws comprise a pair of lateral structures in shape somewhat like a scallop shell. Their outer edges can be opposed so as to grasp an object, or they can move against each other. They are separated dorsally and ventrally by very narrow slits.

An oral capsule is shaped like a hemispherical cup, the opening being circular or oval but never slit-like. The inner

wall of the capsule may bear cutting or piercing organs. The outer edge may be serrated, spiny, or papillate. The capsule is immovable and serves as an attachment organ. The internal teeth can move and can rasp away the tissue to which the cup is applied.

(3) The structure of the œsophagus, whether muscular or triradiate in transverse section, whether capillary and consisting of a delicate tube running through a row of cells, whether muscular and possessing one or two specialised regions or "bulbs."

(4) The occurrence of a caudal bursa, a cuticular expansion surrounding the tail end of the male and used for copulatory purposes. There are two types :—

(i.) A semicircular membranous cup supported by ribs, somewhat like an umbrella (*Strongylidæ*).

(ii.) Lateral folds along the posterior part of the body (*Spiruridæ*).

**Prophylaxis and Treatment of Helminth Infections.**—Preventive methods against helminth infection depend, as regards the details, upon the life history of the helminth whose prohibition is desired.

Measures against helminth parasites in general, however, should comprise :—

(1) A pure water supply. Freedom of water from helminth eggs can be only ensured by a very efficient system of filtering or by heat sterilisation. Bactericidal treatment by chemicals is usually of little effect upon helminth eggs.

(2) An efficient system of latrinage and of disposal of human excreta.

(3) The protection of food-stuffs from flies, rats and mice, and cockroaches.

(4) Abolition of the practice of using human or hog manure in vegetable gardens.

(5) Periodical use of antihelminthic drugs.

Against a helminth parasite the ordinary purgatives, which merely excite peristaltic action of the gut, are of little use, since most helminth parasites can adhere firmly to the gut wall or can wrap themselves round the villi of the mucosa and so avoid being carried down the gut by peristalsis.

There are, however, certain drugs which can affect the parasite through the host blood supply and cause it to relinquish its hold on the mucosa.

The usual method, therefore, followed to bring about the expulsion of helminthes from the animal gut is, in the first place,

to free the gut from the bulk of contained fæces by the use of aperients or water enemata; secondly, to administer the appropriate dosage of an antihelminthic drug; thirdly, to follow this up by the administration of a saline purgative such as magnesium sulphate or calomel.

Against tapeworms, for example, antihelminthic drugs commonly used are alcoholic extract of male fern (*Aspidium filix mas*), pellietierine (an alkaloidal constituent of pomegranate root), and thymol.

The latter drug was formerly the most commonly employed specific against hookworm; its use is not without danger, since it is soluble in alcohol and in fats, and if absorbed into the human system owing to the presence of such substances in the gut, may cause collapse and delirium.

Oil of chenopodium or its alkaloidal antihelminthic constituent *ascaridol* has been found to be more effective and somewhat safer than thymol, particularly against hookworms.

In experimental work in the control of hookworm amongst coolies on tea plantations in India, the drug beta naphthol was found in 1918-20 to possess hitherto unsuspected vermifugal properties. It has, however, the objection that it is seriously toxic to people who have active or latent malarial infections.

Chloroform, again, if dissolved in castor oil, can be given with as much safety in 3 or 4 grm. doses as can other antihelminthics; but unless rapidly eliminated from the system, may cause degeneration of the liver.

Carbon tetrachloride, a substance similar in constitution and properties to chloroform, is a comparative recent addition to the ranks of antihelminthics. It seems to be almost specific for the hookworm *Necator*, but is less effective against *Ancylostoma*. In doses of 2 c.c. for adults it is most efficient in the removal of hookworms, and is safer than is the use of 1·5 c.c. doses of chenopodium or 3 grm. doses of thymol or 4 grm. doses of beta naphthol.

It is cheap, palatable, and easy to administer, particularly useful qualifications for its use in mass treatment of hookworm infected populations. It is dangerous, however, to people whose liver has been already weakened by alcohol or by other causes.

## CHAPTER IX

### ARTHROPODA AND DISEASE: Toxic Inoculation

THE term disease will be used here in a very wide sense to express the appearance of lesions or changes in an animal's tissues, induced by some extraneous influence and inimical to the well-being of the animal. The term Arthropoda will be used to indicate the phylum of animals, which includes insects, spiders, scorpions, ticks and mites, centipedes and millipedes, crustacea, and many other similar forms.

The association between such lesions and Arthropoda may be one of several types.

In the first place, the lesions may be produced by direct inoculation of some toxic substance by an arthropod into an animal host; to this type the term **toxic inoculation** may be applied.

In the second place, the lesions may be caused by the actual presence of an arthropod within the host body; to this condition the term **myiasis** is usually applied, an unsuitable term, because the ability to produce such lesions is not restricted to the larvæ of flies, as the term implies, but is shown by many other arthropods; this type of disease relationship would be more aptly termed **entomiasis.**

In the third place, the lesions may be caused by some organism, usually bacterial, of which the attacking arthropod is a carrier; this type may be termed **mechanical transmission.**

In the fourth place, the lesions may be caused by some organism, usually of a protozoan nature, to which the incriminated anthropod serves as an indispensable and alternative host; to this type of disease production the term **cyclical transmission** may be given.

These various categories are, of course, purely artificial divisions created for convenience of description, and it is not always possible to restrict a particular arthropod type to the one category. Blood-sucking arthropods, such as the mosquito, may be qualified for inclusion within more than one of the categories, since they may cause tissue irritation by their bite, may mechanically infect the host with some bacterial organism,

may infect the host with some protozoan organism which has passed a phase of its life-cycle within them.

The arthropods, which produce lesions by inoculation of toxic substances, may be divided, for convenience of discussion, into :—

(*a*) **Venomous biters,** including certain spiders and camel spiders, certain ticks and mites, certain blood-sucking insects.

(*b*) **Venomous stingers,** including scorpions, bees, and wasps.

(*c*) **Irritant caterpillars.**

The common belief that spiders in general are venomous is unfounded, at any rate as regards their possibility of injuring large animals; and the romantic legends of the remarkable dancing mania or tarantism of mediæval Italy, supposed to be provoked by the bite of the tarantula and curable by a dance termed the tarantella, are based upon the occurrence, among a population exhausted by malnutrition and disease, of epidemic hysteria.

*Lycosa tarantula*, a large spider of Southern Europe, and *Trochosa singoriensis* of Russia, are certainly spiders whose bite is one to be respected but not dreaded by man.

Similarly, as regards the formidable Avicularidæ or bird spiders of Central and South America, although they are sufficiently venomous to kill small birds, especially nestling birds, there is no evidence that they can endanger the life of any large bird or mammal.

There are, however, a number of authenticated records, from different parts of the world, concerning the danger to man of certain small insignificant spiders belonging to the genus **Latrodectus,** of the family Theriidæ, a genus distributed across the world. The bite is said to be painful as the sting of a bee, and to be followed by general rather than local symptoms. The clinical evidence, and evidence derived from the results of injecting extracts from the spider into cats, show conclusively that species of *Latrodectus* possess a venom which is a heart poison and a nerve poison to higher animals. It is possible that the European spider *Chiracanthium nutrix* has a venom with properties similar to those of *Latrodectus*.

The **Camel spiders** or Solpugida of the desert regions of the Old and New Worlds are usually dreaded by the natives of their areas of distribution, despite the fact that there are neither poison glands nor pores in their fangs for the exit of any venomous secretion. On the other hand, the fangs are very

powerful, and secondary infection may lead to severe local effects as a sequel to a bite.

Certain ticks (Ixodidæ) seem able to cause temporary or even complete paralysis of heart or respiratory organs. In particular, *Dermacentor andersoni* (*venustus*) of the United States has been shown to be capable of causing in man and animals a form of paralysis involving the limbs, larynx, and thorax.

Intense irritation of the skin, or dermatitis, may be caused by the members of several families of mites.

The symptoms are similar, irrespective of the species of mite concerned, and consist usually of an intolerable itching of the skin, followed later by an outbreak of wheals or tiny blisters surrounded by a bright red or violet halo.

Frequenters of pasture or harvest fields in late summer or early autumn may be thus attacked by larval stages of the predacious mite **Trombidium.** The adult mite is innocuous, but the minute scarlet larval stage, normally an external parasite of insects, will readily attack the mammalian skin and can cause the most intense irritation for several days. It feeds on the surface of the skin, but can retreat rapidly into a hair follicle or sweat gland, and is thus somewhat difficult to remove, although amenable somewhat to the effect of hot saline baths or applications of sulphur ointment.

Similar dermatitis may be produced by the Tarsonemid mite **Pediculoides ventricosus,** an external parasite of certain grain-infesting insects, upon men handling such infested grain; and various species of Tyroglyphid mites, feeding normally on dried food products, may cause severe dermatitis upon persons handling such substances. Thus *Tyroglyphus siro* is the cause of "grocer's itch," *Tyroglyphus longior castellani* is the cause of "copra itch" in Ceylon, conditions which may be mistaken for scabies.

The irritant effects which follow the bite of such insects as mosquitoes, gnats, bed bugs, fleas, and so on, vary somewhat according to the person attacked, there being considerable variation in personal susceptibility. The effect, too, seems to vary according to the species of mosquito.

A former view regarded the irritant principle as resident in the salivary glands in the form of a hæmolytic substance intended primarily to prevent coagulation of blood whilst the mosquito was feeding, but later experiments suggest that the poisonous action of the mosquito bite is due to an enzyme produced by commensal fungi in the three œsophageal diverticula.

In the case of biting Hemiptera, however, general opinion regards the salivary secretion of the two pairs of salivary glands as being the cause of the irritation produced by the bite, although in the case of the giant bug *Belostoma* the very prominent so-called "cephalic glands" on the ventral side of the head have been suspected.

Of the bugs which are capable of producing bites intensely painful to man, *Belostoma*, certain Reduviidæ such as *Reduvius* and *Conorhinus*, and certain *Cimicidæ* are the most important.

**Reduvius personatus,** the masked bed bug hunter of North America, derives its popular name from its habit of having body and legs completely covered with dust and lint, and from its supposed habit of preying upon the common bed bug. The bite has been described as being almost as painful as that of a snake, and to be followed by swelling and irritation lasting a week.

**Conorhinus sanguisuga,** the "big bed bug" of the Southern United States, is known to inflict a very painful bite, but no satisfactory study of the secretion has been made.

Biting Diptera, other than mosquitoes, comprise the **Simuliidæ** or Black Flies, small black, hump-backed flies haunting notoriously the vicinity of running streams, where their larvæ occur attached to stones, logs, or vegetation. In some regions they are a terrible scourge, and enormous losses have been caused to farmers and stockmen in certain areas of North America and Europe by the attacks of these flies on cattle and poultry. Only dense clouds of smoke produced by the burning of leather, cloth, etc., will keep them at bay.

The minute midge flies known scientifically as **Ceratopoginæ** and called variously sand-flies or punkies, are widespread over the world, and are all persistent bloodsuckers.

The **Tabanidæ** or gadflies are well-known blood-sucking pests of cattle and horses and sometimes of man, and are able to inflict painful bites whose effects last for some hours. Other biting insects that can pierce the skin of man and animals will be discussed in the following chapters.

Venomous stingers comprise the scorpions, among Arachnida, and the bees and wasps among Insecta.

In the case of the **scorpion,** the stinging organ consists of a sharp spine on the last segment of the abdomen, containing a pair of highly developed poison glands. Normally, the sting is used against insects, which are held between the pedipalps of the scorpion and stung by the spine being brought forward, in a curve, over the back.

The effect of the sting upon larger animals is very painful but not necessarily fatal, except to very young or small animals. The effect on mammals is to produce great swelling and intense tenderness at the site of the puncture, and there may be convulsions and death from asphyxia. Desert animals are said to be extremely tolerant to the effects.

The usual treatment against scorpion sting in man is immediate slitting of the wound with a knife, and the application of potassium permanganate crystals to the wound.

Stinging insects belong exclusively to the order *Hymenoptera*, and the sting is in reality a modified ovipositor connected with certain venom-producing glands.

In the case of **bees** the secretion is not, as was formerly supposed, merely formic acid, but is the product of two distinct glands; and although little is known concerning its chemical structure, it appears to be neither of a proteid nor of an alkaloid nature. It is a limpid fluid with an acid reaction, readily soluble in water, coagulable in alcohol. A 2 per cent. aqueous solution shows no irritant action upon the skin, but a distinctly irritant action upon mucous membranes. On the other hand, if injected in the skin or applied to a break in the skin, there is produced a local necrosis accompanied by hyperæmia and swelling.

The danger arising from the stinging powers of bees or wasps to man depends chiefly upon the quantity of poison injected rather than upon the quality. A person in a weak state of health may be seriously affected by the attack of large numbers of the insects simultaneously, and a frequent sequel to a neglected wasp or bee sting is septicæmia, which may prove fatal.

In the case of a single sting from a wasp or bee, the effect is dangerous when the site is on the tongue or in the mouth, where local swelling may produce suffocation.

**Poisonous caterpillars** of many species of butterflies or moths have been described from various parts of the world.

Thus, caterpillars of the Brown-tail Moth (*Euproctis chrysorrhea*), a foliage-eating caterpillar of great economic importance in Europe and north-eastern United States, are liable to provoke serious dermatitis when handled, owing to certain short barbed hairs which readily break off and penetrate the human skin.

The trouble is caused by a poison within the hair which has a hæmolytic action. As is the case with other dermatitis-provoking caterpillars, the hairs occur in bunches of three to

twelve on minute papillæ which cover the surface of the subdorsal and lateral tubercles. According to Kephart, the hypodermis of each tubercle has two types of cell, namely: (*a*) slender, fusiform cells, each of which is a hair-forming cell; (*b*) larger, more prominent cells, one to each papilla, possessing a granular protoplasm with large nucleus. Each of these cells connects by one pore canal with the tuft of poison hairs on the papilla.

The condition known as *ophthalmia nodosa* of man is a nodular conjunctivitis, somewhat resembling tuberculosis of the conjunctiva. The conjunctiva shows a number of yellowish-grey flattened nodules, apparently each formed around the barbed hair of some kind of Woolly Bear or Tussock caterpillar. Numerous cases of this condition have been recorded.

The irritation from nettling caterpillars can be very severe, but relief can usually be gained by weak lotions of ammonia, bicarbonate of soda, or other alkaline substances.

In conclusion, reference may be made to certain insects whose blood plasma contains some substance which has poisonous properties. Thus caterpillars of the European cabbage butterfly, *Pieris brassicæ*, are said to cause severe colic, salivation, stomatitis, or even paralysis of the hind limbs, when accidentally swallowed by domesticated animals or birds.

The *Melœidæ* or **blister beetles** are well known for the possession of a peculiar volatile, crystalline substance, *cantharidin*, in their reproductive organs, and certain species when dried and ground to powder are used medicinally under the term of Spanish Fly as a local irritant, or even internally as a stimulant and diuretic. The flesh of birds which have fed on meloid beetles is stated to be poisonous to man, and cases have been recorded of human beings poisoned by eating the flesh of cattle which, in their turn, have been affected by accidentally eating meloid beetles when grazing.

In South Africa, a Chrysomelid beetle, *Diamphidia simplex*, occurs, whose larva has in its blood a toxalbumin which has a hæmolytic action upon mammalian blood, and is said to produce death from paralysis. Certain Bushman tribes use the body fluid of these larvæ as an arrow poison.

## CHAPTER X

### ARTHROPODA AND DISEASE: Entomiasis

It is preferable to dissociate the term entomiasis from the production of lesions by the accidental or casual attack of arthropods. As already noted, many blood-sucking arthropods, many with acrid secretions, many with irritant hairs, can produce temporary lesions of the animal skin. Eggs or larval stages of arthropods which breed in fruits, vegetables, meat-stuffs, may be swallowed accidentally by animals. Such forms as breed usually in fæces or in carrion may be attracted to septic wounds or to the body orifices of animals which suffer from catarrhal or dysenteric discharges; thus in Europe, larvæ of the house-flies *Fannia scalaris* and *Fannia canicularis*, which usually live in human excrement, are quite frequently expelled from the stomach, rectum, or urethra of man, the victim having been infected by female flies when using an earth privy. Very many cases are known, also, of the blow-flies *Calliphora*, *Lucilia*, *Sarcophaga*, depositing eggs or larvæ in the body orifices or open wounds of animals. On the battle-fields of the Great War such cases were of common occurrence.

The term entomiasis should, in fact, be restricted to lesions caused by Arthropoda which are known to attack invariably, or, at any rate, very frequently, the tissues of living animals, and in particular of healthy, unwounded animals, and which may be incapable of breeding in dead tissues.

Such habitual entomiasis production is associated particularly with the families **Muscidæ, Sarcophagidæ,** and **Œstridæ** of two-winged flies (Diptera), with the family **Sarcopsyllidæ** of fleas, and with several families of Acarina or mites, notably the **Gamasidæ, Trombidiidæ, Sarcoptidæ,** and **Demodecidæ.**

**Muscid Entomiasis.**—The problem of distinguishing between true habitual entomiasis and casual entomiasis is particularly difficult in the case of the *Muscidæ*, that large family of flies whose members are of the house-fly or blue-bottle type.

In almost every sheep-raising country in the world, cases are known of sheep being attacked by maggots of some type of blue-bottle or blow-fly. That many such flies will attack normal

healthy sheep is beyond question, and that many others will lay their eggs only upon wounded or strong-smelling sheep seems also certain. Further, it has been observed that certain species of blow-fly which, within living memory, were restricted, as regards the oviposition habit, to carrion, have passed through a phase of casual entomiasis production and entered upon a phase of habitual entomiasis production.

Among Muscid larvæ which are associated with entomiasis, there occur two varieties of habit: the larva either feeds upon the subcutaneous tissues of the victim, or it sucks the blood. Strictly speaking, the latter habit is not a form of entomiasis, but for convenience the larvæ which possess it will be discussed here.

The Muscid larva is a soft-skinned, white, cylindrical limbless maggot, tapering anteriorly to a pair of mouth hooks and, apart from these, devoid of anything in the way of head. Of the twelve segments which compose the body, the first is provided with a pair of fan-shaped spiracles or breathing organs. The last segment has a pair of posterior spiracles in the form of circular or oval plates perforated with slits. The shape of these slits is of considerable importance in the identification of species of Muscid larvæ.

Each plate may be described as a ring of chitin, within which are three sieve-like openings and a small raised area known as the "button."

Three types of such plate exist (Fig. 18) :—

(1) Chitinous ring intact: button well within the ring, D-shaped, broad; slits are sinuous. This type may be typified by *Musca*, *Pseudopyrellia.*

(2) Chitinous ring intact: button enclosed by the ring itself; slits straight. This type is exemplified by *Calliphora.*

(3) Chitinous ring very thin on lower, inner margin, so that there appears to be a break in it. In this gap the button is situated. Slits straight. This type occurs in *Chrysomyia* and *Cochliomyia.*

The maggot is quite incapable of swallowing or chewing solid particles of food, but has first to liquify the food medium by the secretion of its salivary glands, and then to suck the fluid product into its alimentary canal. The transition to a blood-sucking habit is therefore not so strange as would at first sight appear.

In the case of sheep attacked by blow-flies, the eggs are laid in clusters upon the wool near the root of the tail, and the resulting maggots eat away skin and superficial muscles in that region. The adult flies are not readily deterred from oviposition

by chemical substances applied to the wool, particularly as such substances cannot feasibly be applied at short intervals.

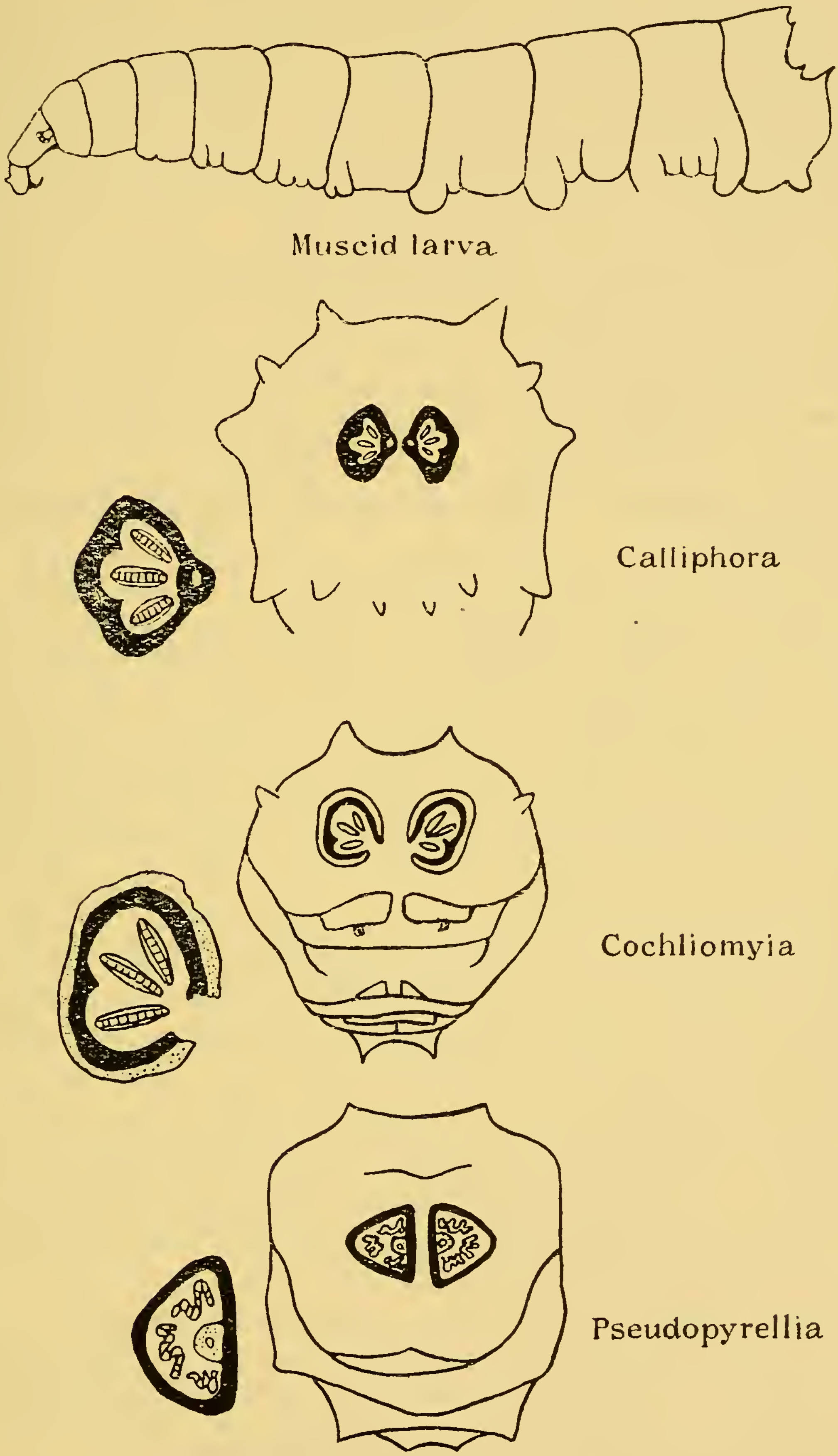



Fig. 18.—Posterior Larval Spiracles of some Common Muscid Flies.

The eggs usually hatch within twelve to twenty-four hours, or, in some cases, living larvæ are deposited and the various larval stages are passed through very quickly.

Sheep dipping, therefore, is impracticable against blow-flies, since in practice sheep would require to be dipped every few days.

In Australia, much is being hoped at present from the establishment of certain European parasites of blow-flies, in particular the Chalcid wasps *Nasonia brevicornis* and *Chalcis calliphoræ*, which are being liberated in numbers in sheep-raising districts. In Great Britain and North-West Europe, **Lucilia sericata** is the sheep maggot fly. In North America, sheep are attacked by **Cochliomyia macellaria,** by **Phormia regina** and by **Lucilia sp.** In Australia, where the problem is acute, several species are concerned. **Chrysomyia albiceps** is the commonest, but it is not certain whether the larvæ of this fly are feeding on the sheep's tissues or are preying upon associated blow-fly larvæ. Other sheep maggot flies are **Chrysomyia varipes, Calliphora (Anastellorhina) augur,** and **Pollenia stygia.**

Probably all these sheep blow-flies are what Patton terms semi-specific myiasis producers, that is to say they attack animals secondarily, breeding mainly in the bodies of dead animals. The same may be said, too, of the notorious Screw-worm fly—**Cochliomyia macellaria**—of North America and Central America, a brassy-green fly which deposits egg clusters, large as a pea, in the body orifices or wounds of horses, cattle, and even human beings.

In man the favourite site of attack is the nasal cavity, particularly the nasal septum and cartilage of the nasal fossæ, and great disfigurement or even death may be caused if the larvæ cannot be quickly dislodged by injections of chloroform or carbon tetrachloride.

A true entomiasis producer, and one which will not breed in dead tissues, is **Chrysomyia bezziana** of India, Burma, Ceylon, and Africa. Its larvæ commonly occur in the nasal, oral, aural, vaginal apertures and the wounds of man and animals, in India, and of cattle in Africa.

A similar habit in Russia is shown by **Wohlfartia magnifica,** which again is believed to breed only on living animals. It is, however, strictly speaking, not a Muscid fly but a member of the related family *Sarcophagidæ.*

In Africa, cutaneous lesions are caused by the larvæ of **Cordylobia anthrophaga** (*Bengallia depressa*) and **Cordylobia rodhaini.**

The first-named species is widely distributed in the grass areas between the Sudan and Senegal and as far south as Natal.

Its larval stage is normally a parasite of dogs, and the female fly oviposits in dust, sand, earth, etc., in places where the host usually lies. The newly hatched larva bores its way through the epidermis and eventually forms a sort of boil beneath the skin of the buttocks and lower limbs.

**Cordylobia rodhaini** is restricted to the damp forests of the Congo, and is normally, in the larval stage, a parasite of duiker antelopes (*Cephalophus*) and of the large rodent *Cricetomys gambianus.*

Throughout Central Africa there occurs a yellowish-brown Muscid fly known scientifically as **Auchmeromyia luteola,** haunting shady places near human dwellings, particularly in the vicinity of latrines. The larvæ occur beneath the mats in native huts, and emerge at night to suck blood.

The larva of **Chæromyia,** a similarly distributed fly, sucks the blood of wart hogs (*Phacochœrus*) and ant-eaters (*Orycteropus*). The adult fly is said to live permanently in the darkest, deepest portion of the wart hog or ant-eater burrow.

The genus **Passeromyia** in the larval stage sucks the blood of Passerine bird nestlings. A similar habit in Europe and North America is shown by **Phormia (Protocalliphora) azurea** and **Phormia chrysorrhea,** the larvæ occurring attached to the tarsi, mandibles, and under-wing surface of nestling birds.

**Œstrid Entomiasis.**—The **Œstridæ** comprise large thick-set flies, somewhat furry and bee-like in appearance, with large heads and rudimentary mouth parts, whose larvæ are exclusively parasitic within the bodies of mammals. The eggs are laid usually upon the hairs of the victim, and the larvæ, which are somewhat barrel shaped and possess rings of dark hook-like spines, either bore directly through the skin or are carried into the host's pharynx by the tongue. The full-fed larva always leaves the host and pupates in the ground. The exact nature of the food of the larva is not understood. It does not appear, however, to consist of blood but of the exudations produced by the irritant action of the mouth hooks on mucous tissues. The adult stage is a short one, the entire larval stage a very long one. The family is divided into a number of sub-families.

(1) Sub-family **Gastrophilinæ.** This group comprises forms whose larvæ live in the stomach of the horse and its allies, and are sometimes termed bots.

Among domesticated Equidæ the commonest species are **Gastrophilus intestinalis, Gastrophilus veterinus,** and **Gastrophilus hæmorrhoidalis.**

The first-named species deposits its eggs upon the long hairs on the side of the forelimb. The eggs require a certain amount of warmth and friction in order to hatch, and these conditions are supplied by the teeth and tongue of an irritated horse. The friction causes the first stage larva to emerge, and this is carried into the mouth on the horse's tongue, reaches the alimentary canal, and spends its life attached to the mucosa of stomach or duodenum.

The second species lays eggs upon the hairs of the lower jaw; the third species lays eggs on the hairs of the lips. In these cases the friction is supplied by the animal rubbing chin or nose against fence or manger, and the larva secures admittance to the alimentary canal in food or water.

The eggs of these species present marked difference, but all agree in the possession of a terminal lid and of two longitudinal flanges that grip the hair. Ten months are spent by the larvæ in the alimentary canal; in the spring following infection, the larvæ pass out with the fæces, pupate in the soil, and eventually emerge as adults for a few days' existence in May or June.

A similar life history probably occurs in the case of the species of *Cobboldia*, parasitic in the stomach of elephants; and of *Gyrostigma* in the stomach of the rhinoceros.

(2) Sub-family **Œstrinæ.** This group comprises forms parasitic in the frontal sinuses of various herbivorous mammals. Eggs are laid within the animal's nostrils; the larvæ are sucked in when the animal breathes. The larval stage is spent within the frontal sinuses or nasal passages. **Œstrus ovis** attacks the sheep. Other species of *Œstrus* attack other ruminants. *Rhinœstrus* attacks horses, pigs, and the hippopotamus. *Cephalopsis* attacks the camel and dromedary.

(3) Sub-family **Hypodermatinæ.** This sub-family contains all those Œstridæ whose larvæ cause cutaneous entomiasis in ruminants. The mature larvæ occur lying just beneath the skin of the back and produce boil-like swellings, with a central aperture through which the larva takes in air, and through which it eventually emerges to pupate in the ground. These boils are termed "warbles."

In the case of **Hypoderma bovis** and **Hypoderma lineata** of European and North American cattle, the eggs are laid on the hairs of the legs of the cattle, and the newly hatched larvæ penetrate the skin near the point where the egg was laid, and slowly migrate to the gullet region, there to rest awhile. They select this region probably because of the greater supply of free oxygen there and the little resistance to growth offered

by the areolar tissue. The later stage larvæ migrate to the subcutaneous tissues of the back, by way of the neural canal, and produce the "warbles."

Similar warbles are produced upon the backs of reindeer by **Œdemagena,** whose eggs have a terminal flap recalling the lid of the Gastrophilus egg, and suggesting the possibility of infection by the mouth.

Remedial measures against warbles are hopeless from the point of view of saving injury to the individual hide. Systematic and collective larva destruction over a wide area would go far to stamp out the fly from cattle-raising countries. The method of larva destruction consists of squeezing out the warbles during winter, or of injecting each one with 1 c.c. of iodine. The ripe larvæ do not emerge normally until March or April, but where cattle are stabled throughout the winter, emergence may be earlier.

(4) Sub-family **Cuterebrinæ.** This sub-family comprises a number of forms whose larvæ are subcutaneous parasites chiefly of small rodents in North and South America, and of squirrels and chipmunks in North America. *Cuterebra tenebrosa* occurs beneath the skin of rodents in the same region.

**Dermatobia hominis** is found in the skin of cattle, and, rarely, of man, in tropical America. The female lays her eggs in packets upon leaves. These packets become attached to the ventral abdominal surface of blood-sucking or sweat-sucking insects which walk over the leaves, in particular of the mosquito *Janthinosoma lutzi* and species of *Anthomyia*, and these insects carry the eggs to the mammalian host. This so-called "macaque worm" is a peculiar pear-shaped larva which penetrates the mammalian skin and forms a local tumour. The other Cuterebrinæ are believed to deposit their eggs on the hairs of the host, and these are licked off and enter the alimentary tract, where the emerging larvæ commence their migration to the subcutaneous tissues.

**Sarcopsyllid Entomiasis.**—One family of fleas, the *Sarcopsyllidæ*, is remarkable in that its members cause direct cutaneous lesions in man and other animals.

**Dermatophilus penetrans** is a flea indigenous to South America, but which has become established in West Africa probably by transportation in slave ships. The fleas occur particularly in sandy places where there is undergrowth, and there they lie in wait to attack the naked feet of passers-by. The female burrows into the skin, especially beneath the toe nails, and owing to the development of eggs she swells up to the

size of a pea. The end of the abdomen protrudes, however, through the host's skin, and through it the eggs are expelled. Secondary infection, following on the attack of large numbers of the "chiggers," as they are termed, may produce tetanus, gas gangrene, and even eventual loss of the toes.

Wherever *Dermatophilus* occurs, it is spread very largely by pigs. Pigs seem, of all animals, the most closely related to man as regards the possibility of parasite nutrition. In previous chapters it has been noted that very many intestinal protozoa and helminthes are harboured by pigs and transferred to man. Blood-sucking Muscid larvæ attack equally man and wart hogs. In Rhodesia, the vector of relapsing fever of man, the tick, *Ornithodoros moubata*, has been found in the burrows of wart hogs far removed from human habitations. It may be noted, too, that the pig louse, *Hœmatopinus suis*, can live a long time on man, and that the human louse, *Pediculus*, can live at least a week on pigs.

Another Sarcopsyllid species, **Echidnophaga gallinacea,** the "stick-tight flea," commonly attacks poultry in nearly all tropical and sub-tropical countries. It collects in dense masses on the heads of poultry, in the ears of mammals, and elsewhere.

**Acarid Entomiasis.**—The mites which produce entomiasis of animals belong chiefly to the family **Sarcoptidæ,** the Itch and Scab Mites.

They may be described as minute, square-shaped mites without any division between cephalothorax and abdomen, with a short conical rostrum formed by a pair of pincer-like mouth parts and a pair of pedipalps, and with four pairs of stumpy legs arranged in two sets, two pairs occurring near the rostrum, two pairs occurring near the posterior end of the body. The tarsi of some of the legs end in a sucker.

Of the five sub-families which constitute the Sarcoptidæ, the *Canestrinœ* are parasites of other insects, the *Analginœ* live within the feathers of birds, the *Listiophorinœ* are cutaneous parasites of bats and other small mammals, the *Cytolichinœ* are subcutaneous burrowers of birds, and the *Sarcoptinœ* are subcutaneous burrowing parasites of mammals and birds.

The lesions produced by the Sarcoptine mites are usually termed scabies, itches, manges.

The principal genera concerned are **Sarcoptes, Notœdrus, Psoroptes, Chorioptes,** and **Otodectes,** and it is permissible to speak of sarcoptic mange, psoroptic mange, chorioptic mange, and so on.

The following key to the genera of *Sarcoptinæ* follows that suggested by Neveu-Lemaire :—

| | | |
|---|---|---|
| Male without copulatory suckers ; foot suckers on the first two pairs of legs in both sexes, and in addition on the fourth pair, in the male | Anus terminal . . . | *Sarcoptes.* |
| | Anus dorsal . . . | *Notœdrus.* |
| Male with or without copulatory suckers ; foot suckers on all legs of the male, on none in the female . . . . . | . . . . . . | *Cnemidocoptes.* |
| Male with copulatory suckers ; foot suckers present | On 1st, 2nd, 3rd pair of legs of male ; on 1st, 2nd, and 4th pairs in female . | *Psoroptes.* |
| | On all feet of male ; on 1st, 2nd, 4th in female . . | *Chorioptes.* |
| | On all feet of male ; on 1st and 2nd in female . . | *Otodectes.* |

**Sarcoptes** is predominantly a burrowing mite. The male and the immature female stages live beneath the loose scales of the stratum corneum or outer layer of the skin, or under the scabs of exudated serum which result from the irritation caused by the bites. The pregnant female burrows down as far as the stratum Malpighii, each female making a separate burrow which may run in tortuous fashion for as long a distance as half an inch. The eggs are laid in the burrow and the extremely minute mite occurs at the bottom of the burrow. As the surface of the skin constantly wears away and is renewed from below, the six-legged larvæ appear on the surface of the skin. When the eggs have hatched, the feeding habits of the parasites produce intense itching of the skin of the host. In man the chief seat of attack is the skin of the finger clefts or the wrists.

The various forms of *Sarcoptes* which occur on domesticated and wild animals are probably mainly biological races of **Sarcoptes scabei,** and though normally restricted to one host species, can establish themselves to some extent upon other hosts. *Sarcoptes scabei crustosæ* is the cause of the so-called Norwegian itch of man, characterised by the presence of white or yellowish crusts on hands, arms, or feet, or even scalp or face. It is more contagious and more difficult to eradicate than is ordinary scabies.

*Sarcoptes scabei bovis* and *Sarcoptes scabei equi* cause sarcoptic mange in cattle and horses respectively, and usually infest the inner surface of the thighs, the under surface of the neck, and the root of the tail. *Notœdrus cati* of the cat was formerly regarded as a species of *Sarcoptes,* but is separated by the position of the anus, which is dorsal instead of terminal as in

*Sarcoptes. Notœdrus cuniculi* occurs on the rabbit. Both are communicable to man but less stubborn to treat than is *Sarcoptes scabei.*

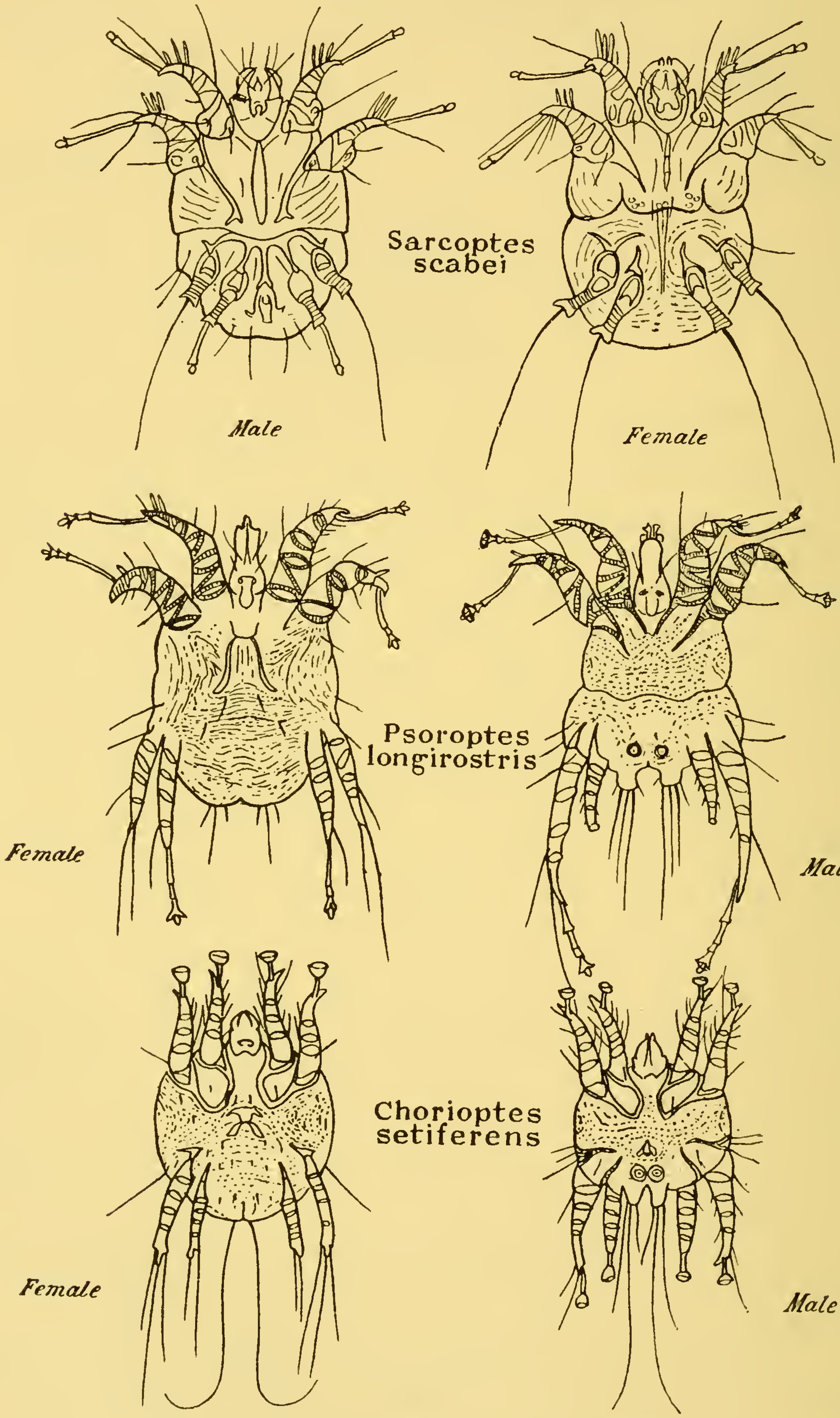



Fig. 19.—The Principal Genera of Itch Mites.

The genus **Psoroptes** lives in groups on the *surface* of the skin, protected, however, by the scabs of exuded serum and pus produced by the irritant bites of the mites.

**Psoroptes communis ovis** is the cause of a very common scab disease of sheep, the so-called sheep scab, one of the most contagious and injurious diseases that affect sheep, and one dating back from the beginning of civilisation. Enormous financial loss is caused in sheep-raising areas owing to the decrease produced in quantity of wool and to the injury and death of animals. Fortunately, the disease is readily amenable to treatment. All stages of the mite are passed on the host, on the skin at the base of the wool fibres, where the eggs are laid, the young mites brought to maturity, and copulation between the sexes carried out.

The life-cycle is short, probably much shorter than was formerly thought to be the case, and varies between eight and fourteen days. The duration of the life-cycle is of some considerable practical importance, since, although dipping or immersion of infected animals in chemical solutions will kill young and adult mites, it will not destroy the eggs; a second dipping, therefore, should follow within an interval sufficiently short to ensure destruction of the immature mites which, in the meantime, have emerged from the undestroyed eggs. Thus, such a second dipping should be not later than ten days from the first one.

Psoroptic mange is also the commonest scab disease of cattle, and although less dangerous than sarcoptic mange, causes greater financial loss to the cattle industry owing to its wider prevalence.

Psoroptic mange is also common among horses.

The genus **Chorioptes** is also the cause of mange diseases in horses, cattle, and sheep. Chorioptic or symbiotic mange, as it is sometimes called, is particularly common among horses. Usually chorioptic mange diseases affect particularly the limbs or the base of the tail.

The species of **Otodectes** frequent the ears of carnivorous mammals. *O. cynotis canis* affects the domesticated dog; *O. cynotis cati*, the domesticated cat. It is prevalent particularly among packs of hounds and on fox farms, and the irritating effect of the parasites within the external ear may produce fits of frenzy or even attacks similar to epilepsy. The mite is similar in structure to *Chorioptes* but the legs are more slender.

**Cnemidocoptes** is a mite which attacks particularly the feet of birds, producing the disease usually called "scaly leg" in

poultry and turkeys. The parasite lives beneath the loose scales which appear between the toes, or under hard crusts, beneath which the tissues are inflamed and septic. Secondary infection may even lead to loss of one or more toes.

In addition to the *Sarcoptidæ*, other families of Acaridæ may cause cutaneous lesions in animals. The family **Demodecidæ** in particular is responsible for the severe follicular manges of domesticated animals. The mite **Demodex** lives in the hair follicles and even in the sebaceous glands, and so becomes very firmly established and difficult to remove. Loss of hair occurs over the regions of the animal attacked, and the surface becomes covered with septic pustules or nodules, the contents of which swarm with the mites. The progress of the disease is slow, but it is practically incurable. The body of the mite is elongate and tapering and the posterior portion is worm-like. The limbs are very stumpy. The follicular mite of man is one cause of the skin condition termed " blackheads," but follicular mange in man is nothing like so serious as it is, for example, in the dog. How the mite is transmitted from animal to animal is somewhat uncertain, but the disease is not highly contagious.

Reference may be made here to the family **Gamasidæ,** a family of mites somewhat resembling small ticks and in the main predatory upon other mites or insects.

**Dermanyssus,** however, is a blood-sucking parasite of birds, hiding by day in crevices and attacking the host by night. *Rhinonyssus* occurs in the nasal cavity of birds, and *Pneumonyssus* has been found in the lungs of monkeys.

Treatment of the various sarcoptid skin diseases consists in principle of the application of toxic chemicals to the skin of the animal attacked. The most effective way of applying such treatment is by " dipping," that is to say, by immersing the animal in a solution of the remedial substance. Cattle or horses or sheep are usually swum through tanks containing a solution of sodium arsenite, or a solution obtained by the interaction of alkalis and sulphur or nicotine, or solutions containing phenols, cresols, pyridine, coal tar creosote, or the like. Small animals can be immersed in warm 3 per cent. solution of potassium sulphide, 2 per cent. solution of creolin, or similar insecticides.

The chemistry of dipping fluids and the technique of applying them is, however, too wide a subject in itself to be dealt with adequately here, and reference should be made to the special literature that has grown up concerning this subject.

## CHAPTER XI

### ARTHROPODA AND DISEASE: Mechanical Transmission

THE potentiality of acting habitually as a carrier of the pathogenic organisms of disease in man or other animals requires of the arthropod concerned :—

(*a*) That it be of common occurrence in the vicinity of such animals.

(*b*) That it be a frequenter of fæcal matter, sputum, or other source of pathogenic organisms.

(*c*) That its structure or habits are such as to convey such organisms from the source of infection to man or the animal concerned ; that is to say, the arthropod must be hairy, or possess the habit of regurgitating food or be a bloodsucker.

These conditions are fulfilled by a somewhat small number of non-blood-sucking arthropods, including particularly the house-frequenting flies, cockroaches, and house ants; and by a somewhat wider range of blood-sucking forms, notably the blood-sucking Muscid flies, the gadflies, the fleas, lice, and bugs.

**House-Flies.**—Of the house-frequenting flies, the most important is undoubtedly **Musca domestica,** which constitutes 90-98 per cent. of the fly population of houses all over the world. To a lesser extent occur **Fannia canicularis,** the so-called lesser house-fly, and **Fannia scalaris,** the latrine-fly.

The genus *Fannia* may be readily distinguished from *Musca* by the fourth vein of the wing, which runs straight to the margin of the wing instead of bending anteriorly as it does in *Musca*. *Fannia*, too, has a peculiar darting motion when in flight, which readily serves to distinguish it from *Musca*.

Several species of blow-fly, *Calliphora* in particular, come into houses. In tropical countries, species of the brassy-green blow-fly *Pycnosoma*, a breeder in human excrement, are also numerous in the vicinity of human habitations.

**Musca domestica** lays clusters of 120-140 eggs generally, but not invariably, in decaying vegetable matter. The favourite site is undoubtedly *fresh* stable manure, to which the female flies are attracted by ammonium hydrate or carbonate in con-

junction with butyric and valerianic acids, according to Richardson ; and, according to Crumb and Lyon, stimulated to oviposit by the carbon dioxide thus given off.

The species of **Fannia** are more catholic in choice of oviposition media, laying eggs readily and breeding readily in rotting paper or rags, so that *Fannia* will breed in quantities in rubbish where the amount of actual vegetable matter is low.

The eggs are laid within the top six inches of the upper surface, and the larvæ, which hatch within twelve to twenty-four hours, according to temperature, work upwards, feeding in the fresh material that is added each day to the surface of the manure pile.

The larva is a typical maggot, a headless, legless, conical creature, provided at the conical end with a pair of chitinous mouth hooks, at the broad posterior end with a pair of oval plates, in each of which occur three S-shaped spiracular slits.

When full fed, which happens within a period varying from five days in the tropics to several weeks in the cold spring or autumn of northern latitudes, the larva migrates downwards towards the dryer portion of the manure pile, usually avoiding the superheated interior of the heap. Periodical forking of a manure heap will, in fact, destroy large numbers of larvæ by precipitating them into the hot interior of a fermenting manure heap.

The larva emerges from the heap usually near the ground-level and at the edge of the heap, rests awhile in order to empty the alimentary canal, and then pupates ; that is to say, it contracts to a cylindrical shape away from the outer skin, which remains around the pupating larva as a dark-coloured, barrel-shaped pupa case.

The migration of larvæ from the manure heap in order to pupate may be taken advantage of, as in the ingenious maggot trap invented by Hutchison at the Maryland Agricultural College of U.S.A., by using as a foundation for the heap a platform of laths, one inch wide and one inch apart, standing above a shallow concrete trough containing weak disinfectant solution. The heap must be kept continually soaked by drenching with water, to induce the full-fed larvæ to leave it and fall into the trough ; otherwise they will merely pupate in the drier parts of the heap.

Within the pupa case the larval organs are remodelled into those of the future fly, and after some days the latter emerges.

The actual total period occupied, from oviposition to maturity

of the succeeding fly, depends upon conditions of temperature, of food, of moisture, and so on. The egg may take eight hours to several days to hatch. The larval stages may occupy five to eight days, or if in non-fermenting food-stuffs, may occupy several weeks. The pupal stage may last from three to twenty-six days. Under favourable conditions of temperature and food medium, however, the period elapsing between generations is about three weeks.

One of the most disputed questions concerning the house-fly relates to the manner in which the winter is spent, and a great deal of somewhat contradictory evidence has been brought forward.

It would seem that the adult fly can spend the winter in a dormant condition in cool, sheltered places such as attics or cellars, but that in heated buildings it is liable to attack by the fungus *Empusa*, and out of doors is killed by frost. In localities where the winter is mild, or beneath large heaps of manure, larvæ or pupæ or even immature flies may survive through the winter. In places where there is warmth, food, and breeding facilities, the house-fly can continue breeding throughout the winter, and probably an over-wintering succession of broods is more common than is realised, particularly in restaurants, bakeries, stables, zoological gardens, and similar places.

When the habits of the adult insect are taken into consideration, its journeys to and fro between the garbage tin, the latrine, the spittoon, and so on, and the food larder or food table, and its habit of vomiting forth a previously swallowed mass of sputum or excrement upon the more tempting food of man, it is not surprising that, once the bacterial origin of infectious diseases had become established, the attention of sanitarians and bacteriologists should be directed with suspicion towards an insect so obviously adapted by its habits and by its hairy body to act as a conveyor of disease. During the past twenty-five years, justification for such suspicion has been amply provided by an enormous accumulation of evidence. An intimate correlation between the prevalence of house-flies and the prevalence of typhoid fever and summer diarrhœa has been fully proved; much evidence has been obtained concerning a similar correlation between house-flies and the occurrence of cholera, tuberculosis, and ophthalmia; and there is a strong suspicion that amœbic dysentery, yaws, anthrax, diphtheria may also be carried by house-flies.

The house-fly is a true intermediate host of three species of *Habronema*, a Spiropteran nematode worm which infests

the stomach of the horse and donkey. The embryos of the worm pass out in the fæces of the host, are swallowed by fly larvæ and remain in the insect right through the metamorphosis, occurring eventually in the head of the adult fly; from thence they pass into the proboscis, are deposited on a horse, and become licked into its alimentary canal.

It has been shown that house-flies are greatly attracted by the eggs of parasitic worms which may occur in fæces or sputum, and try hard to swallow them ; small eggs so ingested pass through the fly uninjured and may be disseminated.

**Prophylactic measures** against house-flies comprise chiefly the removal of stable manure or similar breeding media from the vicinity of dwelling-houses, or the treatment of it with larvicidal chemicals. It is, of course, a difficult matter to hit upon a method of sterilising manure which will kill fly larvæ but not kill bacteria, and so lower the manurial value. A wide range of chemical substances has been at various times recommended. Probably the most efficient are *green tar oil*, mixed with forty parts of soil and used as a surface dressing over the manure heap, *tetrachlorethane* applied to the manure at the rate of two ounces per ten cubic feet of manure, or *borax* applied at the rate of about half a pound per ten cubic feet of manure ; borax is applied with a flour sifter or similar fine sieve around the outer edges of the pile, and two or three gallons of water is then sprinkled over the treated manure. Not more than fifteen tons per acre of such treated manure, however, should be applied to the field ; in fact, if intended for market garden purposes, where large quantities per acre are used, manure is preferable that has been treated with hellebore, rather than borax, at the rate of half a pound to ten gallons of water per eight bushels of manure.

There is, however, one serious objection to the use of larvicidal chemicals, apart from the effect on manurial value, and that is their effect in delaying fermentation and so allowing stable manure to be suitable for fly oviposition longer than it otherwise would be. A more natural method of reducing the number of larvæ in a manure heap is to utilise the heat produced by the natural fermentation of the medium. Before placing a layer of fresh manure on the surface of a heap, the upper layers should be raked away so that the fresh stuff will come into contact with the deeper fermenting manure, and the fresh manure should be covered with a layer of hot manure. Frequent forking over of a manure heap will bring about a considerable diminution in the number of larvæ contained in

it, since large numbers are killed instantly by falling into the hot, deep portions of the manure during the raking.

It should be noted that chemical treatment of manure heaps applies particularly to manure heaps in the vicinity of dwelling-houses. The farm manure heap, far from houses, is little frequented by house-flies, and manure several days old will attract no flies at all. Treatment of farm heaps, however, should be carried out, since they are a prolific breeding source of the stable fly (*Stomoxys calcitrans*).

**Stomoxys** is a small biting fly, similar in size to the house-fly, but easily distinguished from it by the rigid projecting proboscis. It is cosmopolitan and coextensive with the house-fly almost everywhere where horses are kept. It appears, however, to be considerably more abundant in temperate than in tropical countries. It breeds for preference in horse dung or stable manure, but will breed quite freely in rotting cereal straw and in manure too old to attract *Musca*; unlike the latter fly, however, the stable fly rarely breeds in dust-bins or in rubbish tips.

*Stomoxys* is a vicious biter, particularly when the atmosphere is moist. It is of interest from a medical point of view as being a possible carrier of the organism of a trypanosomiasis of horses, cattle, and camels in South-Eastern Asia, known as Surra; as being a carrier of the nematode worm *Filaria labiatopapillosa* which occurs in the peritoneal cavity, and occasionally in the eye, of cattle and deer in India; and in being a suggested carrier of acute epidemic poliomyelitis or infantile paralysis of America and of Europe. The possibility of *Stomoxys* being a conveyor of the latter disease is somewhat doubtful in the light of recent evidence which indicates that the disease is contagious and not transmitted indirectly by insects.

The related Muscid genera *Hœmatobia* and *Lyperosia*, although in habits similar to *Stomoxys*, rarely attack man and are more particularly pests of cattle.

**Gadflies.**—The term gadfly, breeze-fly, clegg, horse-fly, seroot, and so on, refers usually to some member of the family *Tabanidœ*, a family of large, stoutly built flies possessing mouth parts adapted for stabbing and cutting. The flies frequent marshy areas, the eggs being laid in masses on the leaves or stems of marsh plants, and the larvæ live a carnivorous life in damp mud or rotting vegetation, or in the water of the swamp. The males are said to be suckers of plant juices, but the females are persistent and extremely painful biters of man and animals.

The possibility of Tabanid flies acting as mechanical carriers of disease germs has been indicated in several cases.

They have been shown to be capable of transmitting *Trypanosoma evansi* of Surra, of transmitting anthrax, and, with less certainty, of transmitting Leishmaniasis in South America. West African species of *Chrysops* have been incriminated as carriers of the microfilarial larvæ of the nematode worm *Loa loa.*

**Fleas.**—The term flea refers to a type of insect probably possessing close affinities with the Diptera, but sharply marked off as the order *Siphonaptera* by a number of characteristics of structure and habit, in particular by being always wingless, by being laterally flattened, by being always ectoparasites of feathered or hairy warm-blooded animals, and by possessing mouth parts adapted to pierce the cutaneous surface of the host and to suck blood.

From the point of view of successfully identifying any particular species of flea, the particularly important points of structure are the antennæ, the eyes, the combs, and the pygidium.

The antennæ consists each of two small basal segments and a larger oval segment termed the *club*, more or less distinctly divided into nine rings.

The degree of segmentation of the club is an important point in distinguishing different genera. Each antenna lies in a groove on the side of the head. The eyes may be present or absent. If present they are quite conspicuous, black, but non-faceted structures.

The combs are rows of tooth-like bristles which may occur, one on each margin of the cheek or lower edge of the head—the so-called **genal comb**—one on the posterior dorsal margin of the first thoracic segment—the so-called **notal comb.** The **pygidium** is a sieve-like sensory plate which is situated on the dorsal surface of the ninth abdominal segment, and may be flanked by one or more bristles on each side.

The mouth parts of the flea consist of :—

(*a*) A pair of conspicuous triangular, blade-like **maxillæ.**

(*b*) A pair of stout, segmented **maxillary palps** projecting in front of the head, like antennæ.

(*c*) A pair of smaller segmented **labial palps,** which form a tube for the piercing lancets.

These comprise (*d*) a pair of longitudinally grooved, serrated, needle-like **mandibles,** whose apposition form an efferent tube down which saliva passes ; (*e*) an unpaired bristle, the

**epipharynx,** which, by fitting against the mandibles, forms an efferent tube up which blood from the host is sucked.

The eggs of a flea are not glued to the hairs or feathers of the host, but are laid loosely among them so that they fall to the ground. After a variable period of two to twelve days they liberate footless maggots which crawl actively about, feeding on organic débris.

They occur particularly in the sleeping-place or nest of the host; and animals, such as Ungulates, which do not resort to a particular sleeping-place each night, are usually free from fleas; whereas birds, burrowing rodents, or carnivorous mammals are usually infested with them.

Eventually the larvæ spins a minute, pearly-white cocoon within which, after the usual period of quiescence, it pupates. After about a fortnight, the cocoon liberates the fully formed flea. The whole life-cycle may be completed within five weeks.

The majority of flea species are specific, restricting themselves to one particular species of host. Others, however, are wandering fleas, which, although preferring some particular host species, are not averse to other animals if opportunity occurs. It is particularly the species of wandering fleas which is the important one from a pathogenic standpoint.

In previous chapters the intermediate part played by the cat or dog-flea in the life-cycle of the tapeworm *Dipylidium* and the part played by the rat-flea in the life-cycle of *Trypanosoma lewisi* have been alluded to.

The most important example, however, of a pathogenic rôle played by a flea species is afforded by the proved transmission of *Bacillus pestis* of bubonic plague by the rat-flea *Xenopsylla cheopis* of tropical Asia; by the rat-flea *Ceratophyllus fasciatus* of Europe; by the squirrel-fleas *Hoplopsyllus anomalus* and *Ceratophyllus acutus* of California; and by the marmot-flea *Ceratophyllus silantiewi*, in this case conveying pneumonic plague of Manchuria.

The part of the flea **Xenopsylla cheopis** in conveying the bacilli of what is really a disease of the tropical or black rat, *Mus rattus*, from rat to man, was definitely established by the Second Plague Commission of the Indian Government in 1905. Bacot and Martin showed, in 1913, that plague bacilli multiply in the proventriculus of this particular flea species, and the alimentary canal becomes thereby blocked. The flea, receiving no nourishment, becomes ravenous, and as it is still able to suck blood, will attack not only other rats, but will migrate from perishing rats to man. Apparently infection of man is

due to the regurgitation, by the flea, of blood that has been sucked into the œsophagus, into the wound again, bearing with it, of course, masses of plague bacilli.

The common rat-flea of Eastern India, of Madras and Colombo, is a very closely related species, *Xenopsylla astia*, which appears not to suffer from blocking of the alimentary canal by plague bacilli. It is therefore not liable to convey the bacilli from rat to rat, or from rat to man, and the comparative rarity of plague epidemics in these cities, as compared with Bombay, must be ascribed to the predominance of *X. astia* in Madras and Colombo, and of *X. cheopis* in Bombay.

The freedom of Europe and North America from plague epidemics can be ascribed to the fact that, except in seaports, the Black Rat, although frequently imported by shipping, cannot establish itself in competition with the sewer rat *Mus norvegicus*. In mediæval Europe, however, before the Grey Rat had spread from Northern Asia, and when houses were wooden and sanitation non-existent, the Black Rat flourished and plague epidemics were frequent.

*Xenopsylla* very closely resembles the cosmopolitan *Pulex irritans* of man. Both lack the genal and notal combs. *Xenopsylla*, however, shows a vertical chitinous ridge on the mesosternum, the ventral plate to which the basal joint of each middle leg is attached.

The human flea is said to hide by day in cracks and crevices in floors, and in rugs and bedding and so forth, coming out at night to attack human hosts. In some areas the commoner flea attacking man, however, is the dog or cat-flea *Ctenocephalus canis* or *C. felis*. The difference between these two fleas is very slight, but both are easily distinguished from *Pulex irritans* by the possession of both genal and notal combs.

*Ceratophyllus* of rodents and birds includes species which will readily attack man, notably *C. fasciatus* of the Grey Rat and *C. gallinæ* of poultry. *Ceratophyllus* differs from *Pulex* and from *Ctenocephalus* in possessing only the notal combs.

In California, bubonic plague has spread from rats to the ground squirrel *Otospermophilus beecheyi*, probably by the intermedium of the flea *Ceratophyllus acutus*. The danger of plague being conveyed from squirrel to man is, of course, slight, but there is the danger that squirrels may provide a more or less permanent reservoir of disease from which rats may become infected, and through rats, man himself.

In North Manchuria a fur-bearing rodent known as the tarbagan (*Arctomys bobac*) is the primary source of epidemics

of a pneumonic variety of plague which can be conveyed to man and which can spread from man to man directly by sputum contamination.

**Bugs.**—The term bug applies, strictly speaking, to any member of the large insect order of *Hemiptera*, but in a medico-entomological sense refers more particularly to the species of *Cimex*, the " bed bug."

**Cimex** affords a complete contrast in structure and habits to the flea. In the first place it is dorso-ventrally flattened, and is a runner rather than a jumper. In the second place, it does not remain on its host a longer time than is necessary for it to fill its crop with blood, hiding at other times in crevices in panelling, plastered walls or ceilings, wooden furniture, loose wall-paper, and so forth. It is therefore less restricted in its choice of host, a dead mouse or a living cockroach being nearly as acceptable as a human being. It has the most astonishing powers of fasting, cases of adult bugs existing nearly a year without food having been recorded.

In the third place, the life-cycle is without a metamorphosis, the newly hatched insect being a miniature replica of the parent, and attaining sexual maturity and adult size after a series of moults, between which the insect grows and develops further.

The mouth parts are enclosed within a sharp beak-like proboscis, which is bent backwards somewhat beneath the head. This proboscis or *labium* is deeply grooved along its length, and in the groove there lies a pair of needle-like *mandibles*, and a pair of needle-like *maxillæ*; when the mandibles are opposed, a double-barrelled tube is created. Up one barrel, blood passes from the host; down the other there passes a hæmolytic salivary secretion into the wound.

Of the true bed bugs or family **Cimicidæ,** *Cimex lectularius* is the usual form in temperate latitudes ; *Cimex rotundatus* the form in tropical latitudes. The differences between them are slight.

*Cimex columbarius* infests fowl houses and pigeon houses. *Cimex hirundinis* infests swallows' nests. *Cimex pipistrelli* infests the sleeping places of bats.

Of the family **Reduviidæ** or Assassin bugs, the genus *Conorhinus* is the most notorious. *C. infestans* is the " great black bug of the Pampas " of Argentina. *C. sanguisuga* is the cone-nosed bed bug of the Southern United States, the West Indies, and Central America. *C. megistus* is the " barbeiro " of Brazil, the intermediate host of the *Schizotrypanum cruzi* of Chagas Disease.

**Lice.**—The term lice may be applied to two distinct orders of insects, in many respects very distinct morphologically and bionomically, namely, the **Mallophaga** or biting lice of birds and certain mammals, and the **Anoplura** or sucking lice of birds and mammals.

From the pathogenic standpoint, only the latter order need be considered.

They are small, flattened, wingless insects, parasitic on the skin of mammals, and usually possessing modifications of the claws to enable them to cling fast to a hair. The eggs are comparatively large and conspicuous, are glued to a host hair, and the newly hatched louse is a miniature replica of the parent, and reaches maturity by a series of growth phases separated by skin moults.

The mouth parts consist of two retractile tubes, one within the other. The outer tube, considered to be homologous to the labium of other insects, has a serrated edge and serves to anchor the feeding insect to the host skin. The inner tube, representing possibly fused mandibles and maxillæ, is the real penetrating and sucking organ. The host distribution of Anoplura seems to be determined rather by genetic relationships than by geographical factors ; that is to say, a species of louse will be found restricted to a particular species of mammal all over the world.

The genus **Pediculus,** for example, attacks only man and the great apes, and occurs on man all over the world. The genus *Pedicinus* is characteristic of the monkeys, and never attacks man or apes.

The limitation of *Pediculus* to man and apes affords further evidence, to some authorities, of the closer relationship between man and the great apes than between man and the monkeys.

The genus *Pediculus* of man came into prominence during the Great War, owing to an accumulation of evidence that incriminated it as the mechanical carrier of exanthematous typhus, relapsing fever, and trench fever.

There are two species, or more probably two biological races of the one species, namely, *Pediculus humanus capitis*, the head louse, and *Pediculus humanus vestimentii*, the body louse. They coexist with man everywhere, but are undoubtedly less prevalent in hot than in cold climates. The louse-borne diseases are all typical of cold or mountainous rather than of hot, low-lying countries, and are more prevalent in winter rather than in summer. Lice are, of course, more prevalent in such areas, and are more prevalent in winter than in summer, owing

to the wearing by the human host of additional clothing, to a lesser tendency towards thorough body washing in winter, and to greater crowding of sleeping quarters.

The organism of typhus and trench fever is not with certainty known, but a minute organism termed *Rickettsia prowazekia*, resembling diplococci or bipolar bacilli, has been observed in the intestinal epithelial cells of lice taken from typhus patients, and is believed by some authorities to be a life-cycle phase of a protozoan causative organism of typhus. Similar bodies have been observed in the blood of trench fever patients and in the tick *Dermacentor* that conveys Rocky Mountain spotted fever. Other authorities, however, deny that Rickettsia bodies are micro-organisms at all.

Very little information is available concerning the connection between other louse species and animal disease. Impetigo of hogs is essentially a skin disease produced by inoculation of a bacillus (*Bacillus enteridis gœrtner*) into the skin by the louse *Hœmatopinus suis*.

General prophylactic measures against fleas, bugs, and lice will vary somewhat according to the insect concerned.

In the case of fleas, the sleeping places of domesticated animals and flea-infested rooms can be controlled by spraying with 5 per cent. formalin or with 1 in 1,000 solution of corrosive sublimate.

Bed bugs are a stubborn pest to deal with. In a badly infested room or house containing much old woodwork, the only drastic remedy is that of stripping off all paper and fumigating with hydrocyanic acid gas, or, failing this, with sulphur dioxide. If the source of infection can be localised in some particular area of woodwork or of wall, much can be done by injecting crevices with gasoline or with crude creosote.

Destruction of lice require actual contact of the host animal with some toxic substance or pediculicide, either by immersion in a solution of the substance or by application of the substance in the form of a smear or ointment. In the ordinary civilised community, ordinary methods of cleanliness of body and clothing are sufficient to prohibit lice. Under the conditions of field warfare, however, and of savage communities, cleanliness of body and person is not always possible, and recourse has to be made to pediculicidal substances or to louse deterrents.

# CHAPTER XII

## ARTHROPODA AND DISEASE: Cyclical Transmission

THE term cyclical transmission implies that the arthropod vector of the pathogenic organism concerned does not act merely as a mechanical carrier, but that it acts as an essential intermediate host for some phase in the life-cycle of the organism. It follows, therefore, that the type of pathogenic organism thus conveyed is itself animal in nature, and is usually either a protozoan or a nematode worm.

The chief arthropods, in which the potentiality occurs of acting as intermediate hosts of organisms pathogenic to man and domesticated animals, are certain blood-sucking flies, notably the mosquitoes, the tsetse flies, and the Pupiparid flies, and certain arachnids belonging to the order Acaridea or ticks.

It would not, however, be correct to assert that all these forms are proved carriers of pathogenic organisms. Even among mosquitoes the number of species actually known to carry disease is in the minority, and even in a locality where mosquito-borne disease is endemic, only a small percentage of individuals of the incriminated species may prove to be infected. At the same time, all such insects may be looked upon as potential carriers of blood diseases, and to a civilised community their presence is a menace.

**Mosquitoes.**—The term mosquito is applied generally to certain small flies, popularly and somewhat erroneously referred to in temperate English-speaking countries as midges or gnats, which are sharply distinguished from other two-winged flies by certain peculiarities of structure.

These structural peculiarities concern particularly the wings and the mouth parts. The wings are long and narrow and are completely enclosed by the first or costal vein which runs all round the wing margin. The second, fourth, and fifth longitudinal veins all fork, but the third vein is short and comes off from the middle of the second almost at a right angle.

All the wing veins are provided with scales, which may be of several different types.

The anterior wing border has scales almost bristle-like. The posterior border has a fringe of scales of two forms, namely, short, broad **border scales** and long, narrow **fringe scales** of two lengths. The scales on the wing veins usually comprise short, broad **medium scales** which lie flat against the vein, and long, narrower **lateral scales** that stand out on either side of the vein.

Scales occur also on the legs and on the rest of the body.

The head of the mosquito bears a pair of prominent eyes, a pair of antennæ which in the male resemble test-tube brushes but which in the female have scantier whorls of hairs, and a pair of **palps** or organs of touch; these latter organs may be short, or they may be as long or longer than the proboscis.

The proboscis is a conspicuous projection from the head. It consists essentially of a soft, fleshy rod, ending in a pair of small lobes termed **labellæ.** The rod is deeply grooved dorsally, and in this groove there lie (*a*) a pair of needle-like **maxillæ**; (*b*) a pair of lancet-like structures, the modified **mandibles**; and (*c*) a median tube consisting of (i.) a long grooved incomplete tube, in section like the outer cover of a cycle tyre, that is to say, incomplete ventrally, and (ii.) a blade-like structure that fits against this ventral slit and converts it into a tube; this blade-like structure is termed the **hypopharynx**; the ventrally grooved structure against which it fits is termed the **labrum epipharynx.** The tube formed by apposition of hypopharynx to labrum epipharynx serves for the upward suction of blood or plant juices. A channel tunnelled in the hypopharynx serves for the downward passage of saliva.

In the male mosquito the food consists of plant juices only, and the maxillary and mandibular lancets are absent. Only the female mosquito is capable of biting animals. It must be clearly understood that when the proboscis is thrust against the surface of an animal's skin, the labium bends back and acts as a guide for the lancets and for the labrum epipharynx and hypopharynx. That is to say, the proboscis, strictly speaking, is not thrust into the animal's skin, as is the case with the proboscis of a biting Muscid fly or of a bug. The bite of a mosquito is thus not so painful as is the bite of, say, *Stomoxys*, or a Tabanid fly or a bed bug.

Once the lancets are inserted in the host animal, the powerful pharyngeal muscles which take up almost the whole of the head cavity enable the insect to suck blood from the victim up the epipharyngeal tube into the pharynx. When these muscles relax, the walls of the pharynx collapse and the blood is forced into the œsophageal region, which is provided with a

large ventral outgrowth and two smaller ones, usually termed **reservoirs,** but whose function is disputed. The more modern view is that they contain carbon dioxide and a commensal

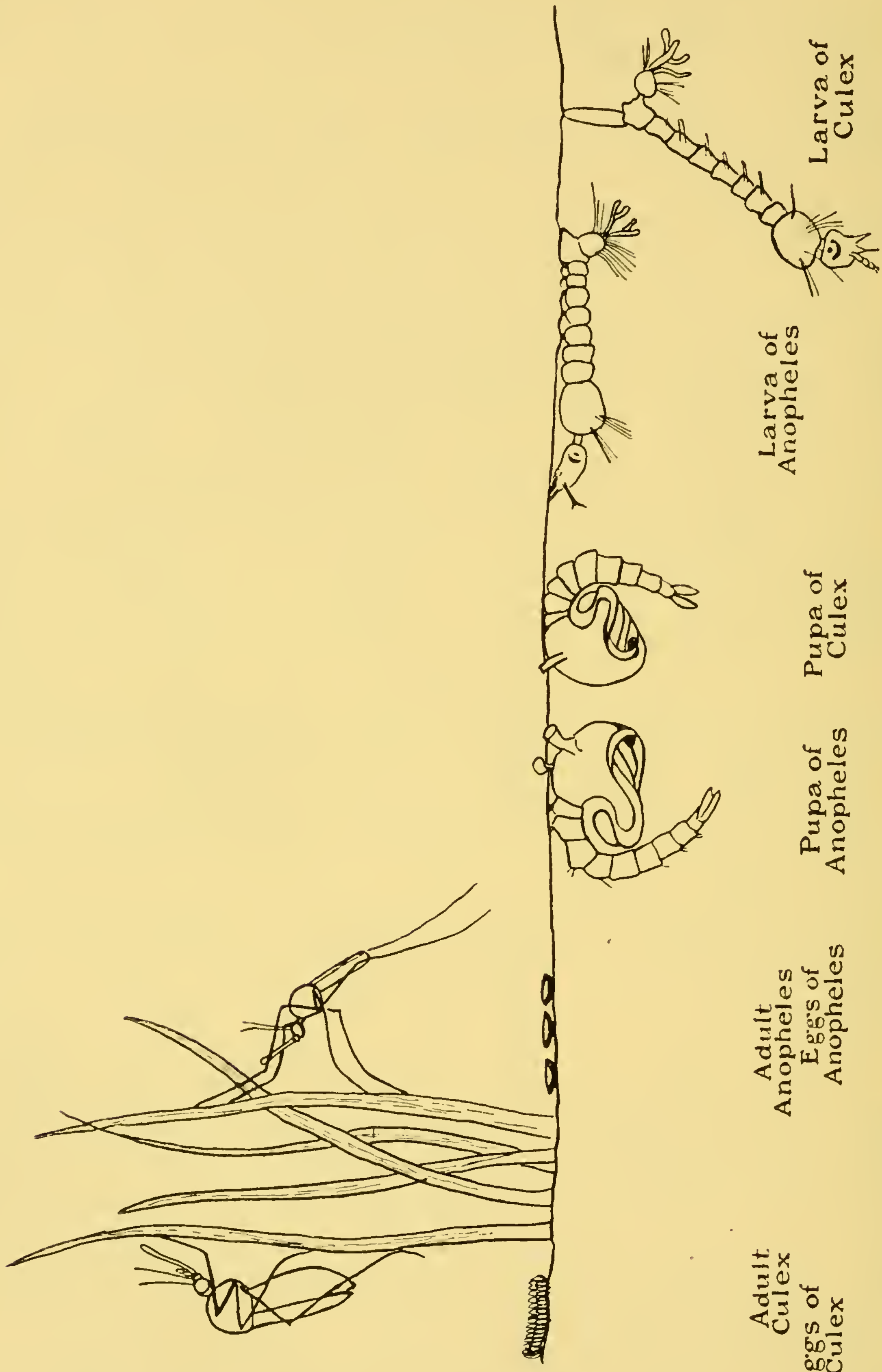



FIG. 20.—Life-Cycle Stages of Culicine and Anopheline Types of Mosquito. (After Stephens and Christophers.)

fungus, and that their contraction forces the gas and fungus into the wound made by the insect and so brings about the irritation which follows a mosquito bite. From the œsophagus the food passes to the real absorptive portion of the alimentary canal,

the **midgut,** whose swollen posterior end is usually but erroneously termed the stomach, and from thence the unabsorbed residue passes by the hind gut to the exterior. On either side of the pharynx there occur three **salivary glands.** Their ducts converge into a single median one that ends in a salivary pump by which the flow of saliva down the duct of the hypopharynx is regulated. In a Plasmodium-infected mosquito these glands are the site of the sporozoites (Fig. 9).

**The Distribution and Life-Cycle.**—Mosquitoes are cosmopolitan in range. In tropical regions, of course, there is greater variety of species and they are prevalent all through the year, but in Arctic latitudes during the short summer the abundance of mosquitoes is probably more intense. The former view that the blood-feeding habit is essential for the propagation of the species is not correct. Swarms of mosquitoes occur in localities where their chance of a meal of animal blood is slight. Areas in Greenland, practically destitute of terrestrial mammals, swarm nevertheless with mosquitoes. Probably both male and female mosquitoes habitually suck plant juices. They are strongly attracted to warm surfaces, and such thermotropic reaction towards the bodies of warm-blooded animals may have brought about the transition in habit from plant sucking to blood sucking.

The life-cycle is very constant throughout the group.

The **eggs** are nearly always laid upon the surface of water, either in raft-like masses (Culicine mosquitoes) or singly and provided with a pair of floats (Anopheline and Stegomyine mosquitoes) (Fig. 20).

Species which lay eggs in rafts usually avoid running streams or agitated pools, and select temporary puddles and the shallow margin of protected pools. Salt marsh mosquitoes oviposit when the meadows are almost dry, and the eggs will remain unhatched for months or even years until covered with water again. Of the forms which lay eggs singly, those whose eggs hatch quickly, such as species of *Anopheles*, frequent open, permanent swamps or clear pools containing weeds and algæ, whilst others which lay eggs that sink down to the bottom of the water and remain unhatched for nearly a year prefer evanescent woodland pools.

The resulting **larvæ** are always aquatic and, as regards respiratory habit, may be divided into five groups:—

(1) Larvæ which hang head downwards from the surface film by means of a posterior respiratory tube (Culicine mosquitoes).

(2) Larvæ which are suspended from the surface film by branched hairs and lie parallel to it, their breathing tubes opening on the dorsal surface (Anopheline mosquitoes).

These two types were formerly believed to depend entirely upon atmospheric oxygen, but recent experiments seem to indicate that oxygen dissolved in the water may be absorbed through the branchial leaflets and the body surface.

(3) Larvæ which live a pelagic life and breathe dissolved oxygen through the body surface. This is the case with the larvæ of the non-blood-sucking genera *Corethra* and *Mochlonyx*.

(4) Larvæ which breathe oxygen contained in submerged water plants. Thus in the Panama Canal zone, *Tæniorhynchus titillans* attaches its eggs to the under surface of a leaf of the water lettuce (*Pistia*). The young larva descends into a mass of rootlets, pierces one with its pointed respiratory siphon, and so takes in air from the plant, remaining thus attached.

The larva of *Aëdes* is believed to penetrate plants in similar fashion with its antennæ.

(5) Larvæ which possess air tubes but which frequent the bottom of stagnant pools and are provided with large gills.

The water need not be pure. Some species breed in clear pools or springs. Others prefer stagnant water or even sewage. Others are brackish water forms, in salt marshes, or even in rock pools, containing as much as 60 grm. of salt per litre.

In general, the larva feeds on algæ or on minute organic matter swept into its mouth by currents produced by tufts of mouth bristles ; others are predacious upon other mosquito larvæ.

The pupal stage of the mosquito is also aquatic and motile, and provided with a pair of respiratory siphons, but of course does not feed.

Mosquitoes may be roughly divided according to habitat into salt marsh forms, swamp forms, woodland and jungle forms, and domestic forms. Their scientific classification is somewhat chaotic, a consequence of the new species and new facts which are discovered almost daily.

For practical purposes, however, we may recognise two distinct groups of species, namely :—

(*a*) The **Anopheline mosquitoes,** and (*b*) the **Culicine mosquitoes.**

**Anopheline mosquitoes** are characterised by the following points (Fig. 21) :—

(1) The female possesses palps as long as the proboscis.

(2) The wings are generally, but not invariably, spotted with patches of dark scales.

(3) The adult rests upon a surface with its body at an angle to it, thus appearing to stand on its head.

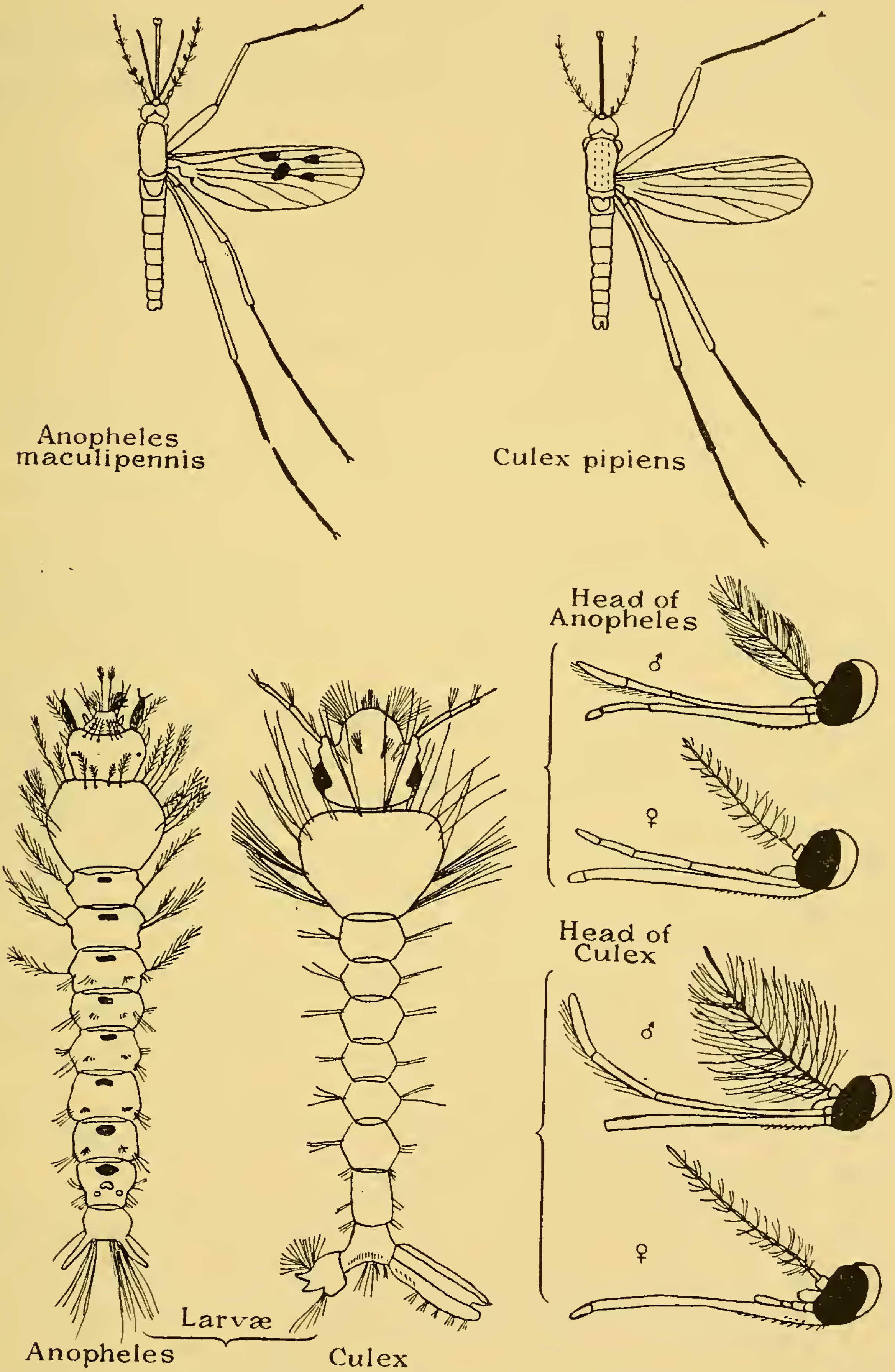



Fig. 21.—Diagnostic Features of Culicine and Anopheline Mosquitoes. (After Brumpt.)

(4) The larva is a surface feeder and floats parallel to the water surface, moored to the surface film by lateral tufts of brached hairs on the abdomen ; there is no posterior respiratory tube, but the tracheal trunks converge to a hollow at the base of a papilla on the dorsal surface of segment 8 ; the body has long, feather-like hairs (Fig. 20).

The chief genera of Anopheline mosquitoes are **Anopheles, Myzomyia, Pyretophorus, Arribalzagia, Myzorhynchus, Nyssorhynchus.**

These are the forms chiefly concerned in the transmission of malarial fever. It may be noted that in Great Britain three species of *Anopheles* occur, two of which are potential malarial carriers, namely, *A. maculipennis* and *A. bifurcatus*, the latter of which is a form whose wings are not spotted.

**Culicine mosquitoes** are characterised by the following points (Figs. 20 and 21) :—

(1) The female possesses palpi shorter than the proboscis.

(2) The wings are usually unspotted.

(3) The adult rests upon a surface with its body parallel to it.

(4) The larva possesses a posterior breathing tube, and hangs head downwards in the water with the tip of this tube applied to the surface film ; the position is due partly to the heavy head and jaws.

The chief genera of *Culicine* mosquitoes are **Culex, Stegomyia, Mansonia, Aëdes.**

*Culex pipiens* and *Culex fatiguans,* two cosmopolitan species, have been shown to convey the larvæ of *Filaria bancrofti* and to act as intermediate hosts to the organism of bird malaria (*Plasmodium præcox*). *Culex fatiguans* is suspected also to carry the organism of Dengue Fever.

*Stegomyia* and *Aëdes* are small black mosquitoes with snow-white markings on head and thorax, and white crossbands on the abdomen. They are popularly termed " tiger mosquitoes." They usually bite at daybreak.

*Aëdes argenteus* is the intermediate host of the organism of Yellow Fever (*Leptospira icteroides*).

It is essentially a house-frequenting mosquito of tropical coast-lines and river banks, and is the commonest mosquito occurring on ships. Yellow fever has therefore probably been carried by ships from the chief endemic foci—the coast-line of South and Central America—across to West Africa, northwards to the southern United States, and to other parts of the world. The spirochæte of yellow fever was of course only described by

the Japanese worker Noguchi at Guayaquil in 1918, but its connection with *Aëdes* was suggested by the brilliant experimental work of the American Yellow Fever Commission of 1900, and has since been fully confirmed by the results of anti-Aëdes work in yellow fever areas.

This mosquito is essentially a domestic species, and is rarely found breeding at more than a hundred yards from human habitations. The black eggs are laid singly at night upon the surface of almost any accumulation of filthy water, however small; they are very resistant and are apparently not affected by evaporation of the water. The larvæ, distinguishable by their transparency and by the short black respiratory siphon, can live in large numbers in extremely small quantities of water, and so are very susceptible to anti-mosquito measures. Such measures, together with careful isolation of yellow fever patients from mosquitoes have almost stamped the disease from many tropical cities.

**Anti-mosquito Measures.**—Measures against mosquitoes in the vicinity of habitations comprise :—

(1) **Drainage,** where water can be disposed of.

(2) **Use of larvicides,** where water cannot be drained and is not required for domestic or commercial use.

(3) **Oiling,** where water is thus required or where conditions militate against the use of larvicides.

Drainage problems occur in connection with lakes, swamps, ponds, and their solution varies according to the source of the water. Rainwater ponds and swamps are usually dealt with by the provision of "V-shaped" ditches, preferably lined with concrete, to carry off water left behind after the main flood waters have passed. If, however, the pond or swamp be a basin in a channel of a sluggish stream, the problem is more difficult, since the water supply is continuous and fluctuating; the usual treatment is to deepen the stream below the basin so as to increase the outflow.

The destruction of mosquito larvæ in large ponds and lakes is possible to some extent by the encouragement of fish, but their use is very limited. The stock of fish constantly requires replenishment, as the small fish are themselves devoured by larger fishes.

Larvicides are as a rule too expensive for large scale use unless chemical by-products are available. Sodium cyanide at the rate of 1-100,000 parts of water is frequently recommended. Cresol is also an effective larvicide. In the Panama Canal zone a black liquid resin soap, prepared by boiling

together resin, soda, and crude carbolic acid in the proportions of 5 : 1 : 40 by weight, is used with great success, one part of it in 5,000 of water being sufficient to kill an Anopheline larva in ten minutes. This larvicide, however, does not emulsify in brackish water, is affected in efficacy by the presence of decaying vegetation, and is fatal to fish. Paris green (copper aceto-arsenite) is also becoming much used as a larvicide.

Oiling in principle consists in the application of a thin film of mineral oil to the surface of the water. The exact toxic action of mineral oil upon mosquito larvæ is disputed. It has been asserted (1) that the larvæ are suffocated ; (2) that alteration in the surface tension of the water renders the larvæ unable to hang on ; (3) that the larvæ are poisoned by oil dissolved in the water ; (4) that the larval spiracles become choked.

The most recent and probable view is that it is the vapour which actually kills, and that the lower the boiling point of the oil used, the more toxic it will be.

No definite type of oil can be recommended above all others.

Ordinary kerosene is effective, spreads rapidly, and forms a thin film ; but it evaporates quickly and the film is difficult to see. It is preferable when mixed with crude oil in proportions varying from 3-1 to 1-3. The most satisfactory mixture is nearly black in colour and slightly thicker than kerosene. On stagnant water such a mixture can be applied as a spray ; where there is a current, various devices are used—drip cans, bags of oil-soaked waste, for example. Small accumulations of water, such as hoof-prints, can be quickly and effectively treated with oil-soaked sawdust. In the Panama zone crude oil of asphaltum is extensively used, half a million gallons per annum, according to one authority ; it is cheap, but its poor spreading qualities would make it unsuitable to cooler climates.

Vegetable oils give more permanent films than do mineral oils, but do not spread so easily. A mixture of two parts of castor oil to 100 of kerosene, however, spreads even better than kerosene, is more permanent, and the film is not readily broken up by wind or by vegetation.

Such oiling should be repeated every ten or eighteen days.

Many cases occur where drainage and oiling methods cannot readily be carried out, notably the cases of rapidly flowing hill streams and the case of rice fields.

The first case can usually be dealt with by the erection of dams to allow sufficient accumulation of water to flush the stream bed from time to time.

Rice fields are very difficult to deal with, since they are too shallow usually for fish, and of course cannot be treated with chemicals or with oil. Alternate drainage and flooding every fortnight has been tried in British Guiana, but this adds considerably to the cost of cultivation. Rice cultivation is in fact inseparable from the occurrence of mosquitoes in large numbers, but it must be remembered that rice-growing areas may be remarkably free from malaria. Many notorious mosquito carriers of malaria will not breed in rice fields.

Reference may be made to two families of flies whose members are closely related to the mosquitoes, namely, the **Chironomidæ** or true midges, and the **Psychodidæ** or owl midges.

The first family has one sub-family, the *Ceratopogoninæ*, whose females are bloodsuckers. They are minute flies, generally blackish in colour. A mosquito net is no obstacle to them, and they can bite through a stocking. The chief genera are *Ceratopogon*, *Culicoides*, and *Johanssienella*. They breed in water or in moist vegetable matter in woodlands, under decaying bark, etc.

They have not yet been shown to transmit any disease.

The Owl Midges are minute hairy flies, somewhat resembling tiny moths, which breed in decaying organic matter, in sewage, etc. There is one blood-sucking genus, *Phlebotomus*, the sand-fly, one species of which, *Phlebotomus pappatasii*, has been shown to carry the *Pappataci* fever of Mediterranean countries. This fly is found commonly in the vicinity of old ruins, walls, or rock heaps, owing probably to the prevalence in such places of lizards, upon which the flies are believed to feed normally, and owing to the conditions in such places, moisture, coolness, and darkness being optimum conditions for the larvæ. The latter are eyeless and haunt dark crevices among rubbish. They feed chiefly on the excreta of wood-lice, lizards, and bats.

**The Tsetse Flies.**—The term *tsetse* refers to the genus **Glossina** of muscid flies, a blood-sucking genus restricted in distribution to Africa, and sharply distinguished from other Muscidæ by the fact that the mature fertilised female gives birth to a single larva, large nearly as the abdomen of the mother, at intervals of several days; the hatching of the egg and the nourishment of the three larval stages takes place in the uterus. The extruded larva has the mouth parts and alimentary canal reduced to vestiges, and so cannot feed; it buries itself immediately after birth in earth or sand, and within a few hours has changed into a pupa.

The shape of this pupa and certain peculiarities of antennæ

and wings shown by the adult may be understood by reference to Fig. 22.

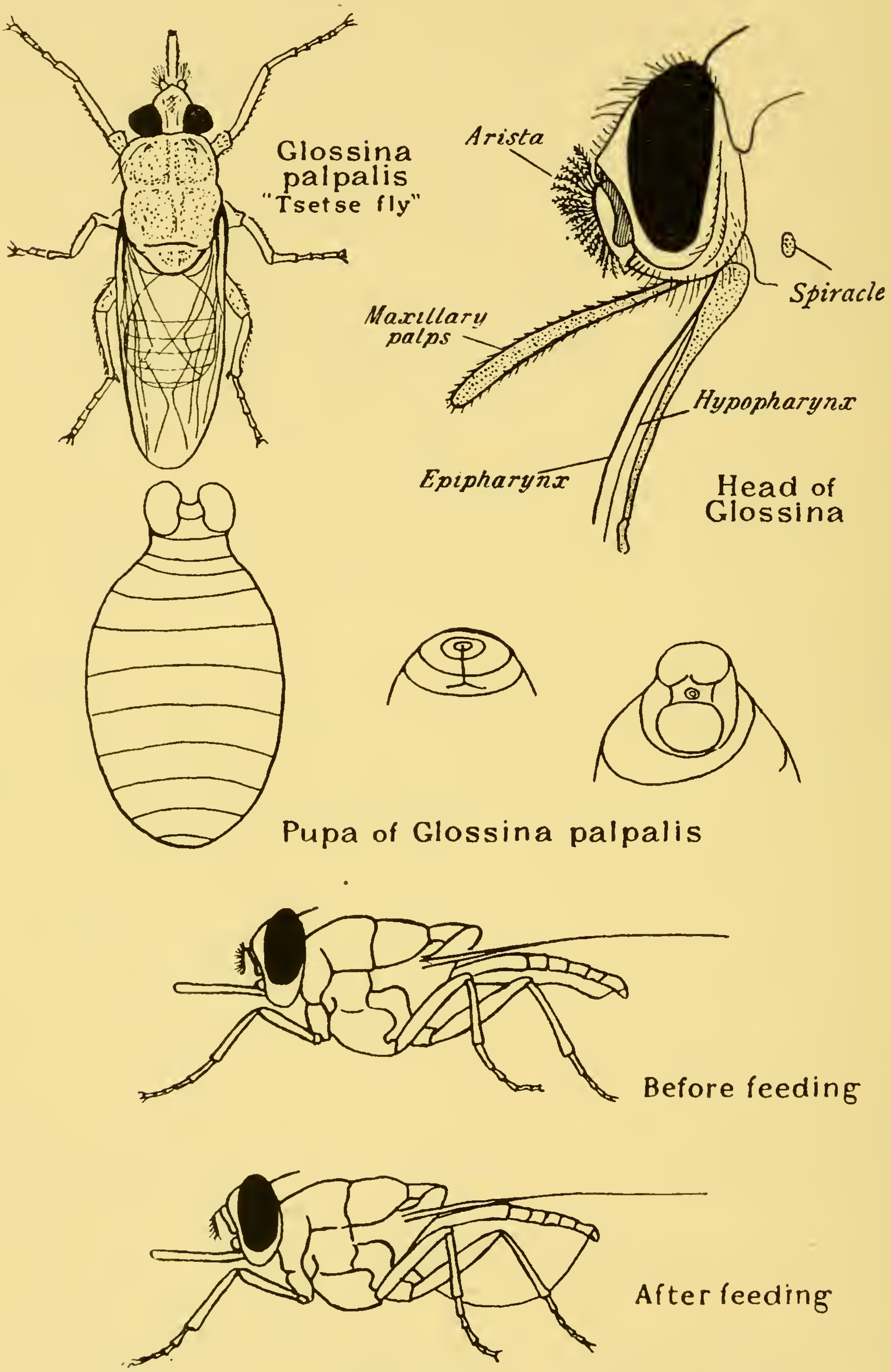



FIG. 22.—The Characteristics of *Glossina*. (After Alcock, Brumpt and Austen.)

The genus is at present restricted to areas of Africa lying between 18° N. and 31° S.; probably it was more widely distributed in former times. Several fossil tsetse flies have been found in the Miocene strata of North America. a palæontological

discovery which throws a light upon the disappearance of ungulate fauna, horses in particular, from America since the Tertiary period.

The prevalence and distribution of tsetse flies is influenced greatly by conditions concerning the prevalence of game animals, the presence of vegetation, and weather conditions. They are therefore not found continuously across Central Africa, but are confined to certain districts known as "fly-belts." Outside such belts there would seem to be factors inimical to the tsetse; probably the absence of moisture is one such factor. The fly-belts, in the case of the majority of tsetse species, are usually regions affording deep shade and proximity to water, together with dry, loose sand or soil convenient for the pupation of the larva; such conditions, in fact, as are provided by the wooded shores of lakes and rivers. The most widely distributed species, however, *Glossina morsitans*, seems less dependent upon the presence of water but requires, in particular, moderate but not excessive cover and a hot, moderately dry climate such as is provided by savannah or parkland where game is abundant. It occurs usually all the year round in certain places where the vegetation is non-deciduous, so-called *dry season foci* or *primary centres*, such places, for example, as a dried up stream bed where there is subsoil water. It must be emphasised that these dry season foci are the areas to which the term fly-belt should be applied in the case of *G. morsitan*, for during the rainy season the fly may range over a wide extent of bush country.

The classification of the species of *Glossina* is based largely upon the characters of the male and female external genital organs. Three distinct groups of species may thus be distinguished (Fig. 23).

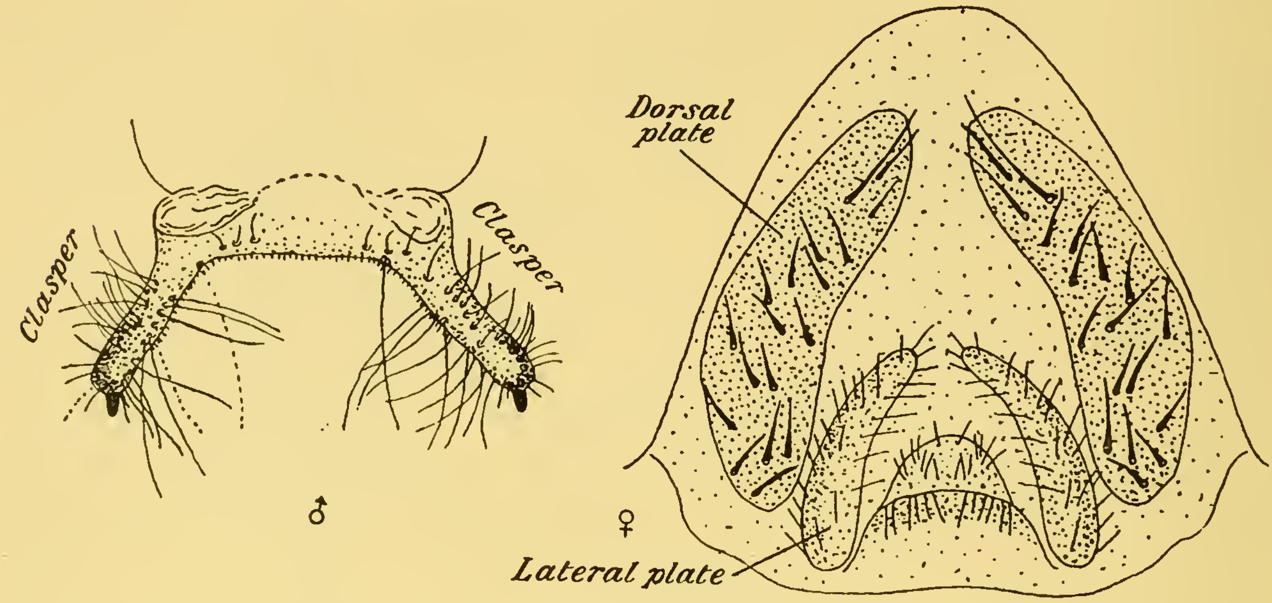
In the **fusca group** the males have the large claspers more or less claw-like and not united by a membrane. The external genital armature of the female consists of five plates, one dorsal pair, one lateral pair, and a single median sternal one (Fig. 23).

This group contains large forms somewhat varied in habitat.

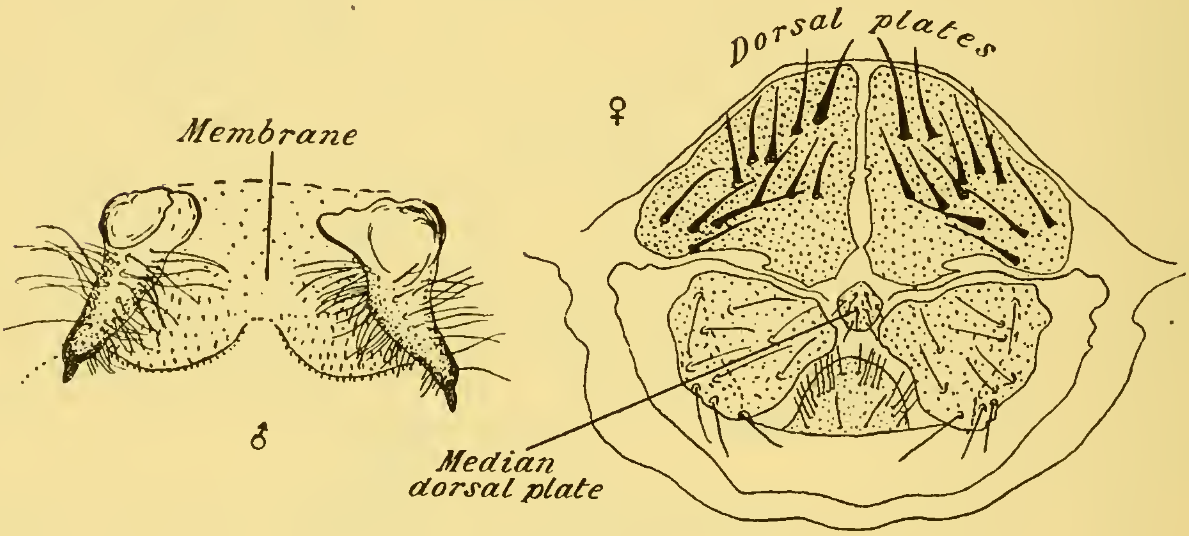
*G. fusca* itself is a large form with dark wings which inhabits the forest areas of West and Central Africa, and is not so dependent upon proximity to water as are other species. It rests during the day and feeds during one or two hours after sunset.

*G. brevipalpis* is the common large tsetse of Southern Central and Eastern Africa. This species again is active in the early evening and the early morning.

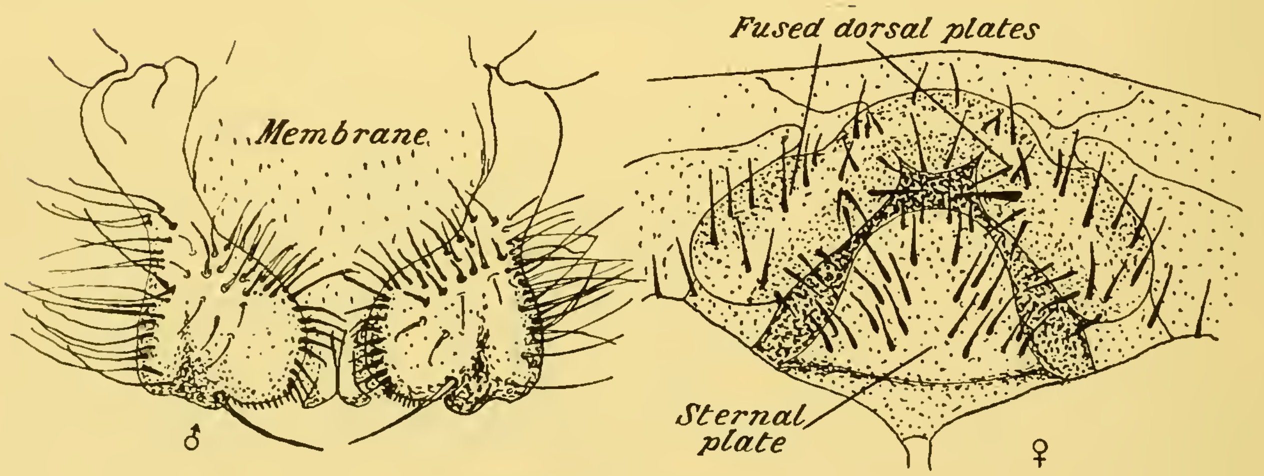
In the **palpalis group** the males have the large claspers connected by a thin membrane, which, however, is deeply




Fusca Group.




Palpalis Group.




Morsitans Group.

FIG. 23.—External Genitalia of *Glossina*. (After Newstead, Potts and Evans.)

divided in the middle. The external armature of the female consists of six plates, a small median dorsal plate being present

in addition to those described above. This group contains particularly the species *Glossina palpalis* and *Glossina tachinoides*.

*G. palpalis* occurs along the edges of rivers and lakes where the vegetation is dense, but occasionally, as along the shores of Lake Tanganyika, where there is little shade. It is probably a true intermediate host of *Trypanosoma gambiense*, the organism of human sleeping sickness, and is probably the only carrier. It is also a carrier of the cattle trypanosomes and of the crocodile trypanosome, since it feeds freely upon these animals.

*G. tachinoides* is one of the smallest of tsetse flies, and is similar in habits to *palpalis*. It prefers, however, the upper reaches of rivers, and is prevalent particularly in the districts along the southern border of the Sahara Desert. It is, too, the only tsetse fly which occurs outside Africa, since it occurs in Southern Arabia. It seems to rely chiefly upon the blood of reptiles, particularly the monitor lizard and the crocodile, but is a carrier of the cattle trypanosomes *T. cazalboui* and *T. dimorphon* in West Africa.

In the **morsitans group** the males have the large claspers completely united by a membrane, and they are also fused in the middle line (Fig. 23). The armature of the females consists of a pair of fused dorsal plates and a median sternal plate. The group includes *G. morsitans*, *G. longipalpis*, *G. pallidipes*, and others. All are flies which haunt open country with a moderate amount of shade but not necessarily in proximity to water.

Of the three chief species, *longipalpis* is essentially West African, *pallidipes* essentially East African, and *morsitans* a species distributed in fly-belts from Senegal on the west coast to Zululand on the east coast. *G. morsitans* is probably the carrier of more trypanosome diseases than any other tsetse. It has been shown to be the carrier, and probably the only carrier, of *T. rhodesiense*, the organism of the virulent Rhodesian form of sleeping sickness; it is the carrier of *T. brucei*, the organism of the cattle disease Nagana; it is also the carrier of several other trypanosome diseases of cattle and horses.

**Anti-glossina Measures.**—The chief measures advocated against tsetse flies are as follows:—

(1) The clearance of scrub and undergrowth from the banks of rivers and for three hundred yards around villages, or, in the case of the wide ranging *morsitans*, the destruction in the dry season of located primary foci.

(2) Elimination of game animals from the fly-belts has been advocated by many authorities, but in the absence of fuller knowledge the value to be derived from such measures is a matter of dispute. It is not proved that trypanosomes of game animals become pathogenic when introduced into domesticated animals ; it is not certain whether other animals, reptiles, and rodents, for example, may not also serve as trypanosome reservoirs ; it is not clearly known whether the tsetse flies are dependent for food supply upon game animals, or whether they have other sources of supply, or can live on plant juices.

(3) The collection and destruction of pupæ has also been recommended. The difficulty of applying such measures and the trapping of adults on a large scale are almost insuperable.

**Pupiparid Flies.**—Pupiparid flies, like tsetse flies, give birth to full-grown larvæ, one at a time, which pupate almost immediately after birth.

The flies themselves are blood-sucking ectoparasites chiefly of mammals and birds, but one form, *Braula cæca*, exists on bees.

They are characterised by a tough, leathery outer skin, a head which is jammed back against the thorax, or even turned back upon it, by the broad thorax, the reduced antennæ, the stout legs ending in remarkably strong grasping claws. The proboscis is somewhat like that of *Glossina*, but is retractile. Wings may be present, may be vestigeal, may be present for a short time only, or may be altogether absent.

Of the various families which make up the group, the **Hippoboscidæ** are parasitic on birds and mammals. *Hippobosca* attacks cattle, horses, and sheep. *Melophagus ovinus* is the " sheep ked." Both genera are hosts of the crithidial stages of mammalian trypanosomes.

The **Streblidæ** are parasitic on bats.

The **Nycteribiidæ** also infest bats.

The **Braulidæ** include the pupiparid parasite of bees.

**The Ticks.**—The term " tick " is applicable to a member of the acaridean family **Ixodidæ,** the remaining families of Acaridea constituting the so-called mites. They are, of course, not insects but Arachnida, that is to say, belong with the spiders, scorpions, etc., and so are characterised by the division of the body into two regions, cephalothorax and abdomen, and by the possession of not more nor less than four pairs of walking limbs.

As in the case of all Acaridea, the body is unsegmented, and

owing to the fusion between cephalothorax and abdomen, is globular. At the anterior end is a depression, the **camerostoma,** into which the mouth parts are inserted. These are collectively termed the **rostrum,** or, more correctly, the **capitulum** (Fig. 24).

A typical adult tick ranges in size from that of a pea to a hazel nut. The capitulum consists chiefly of a quadrangular

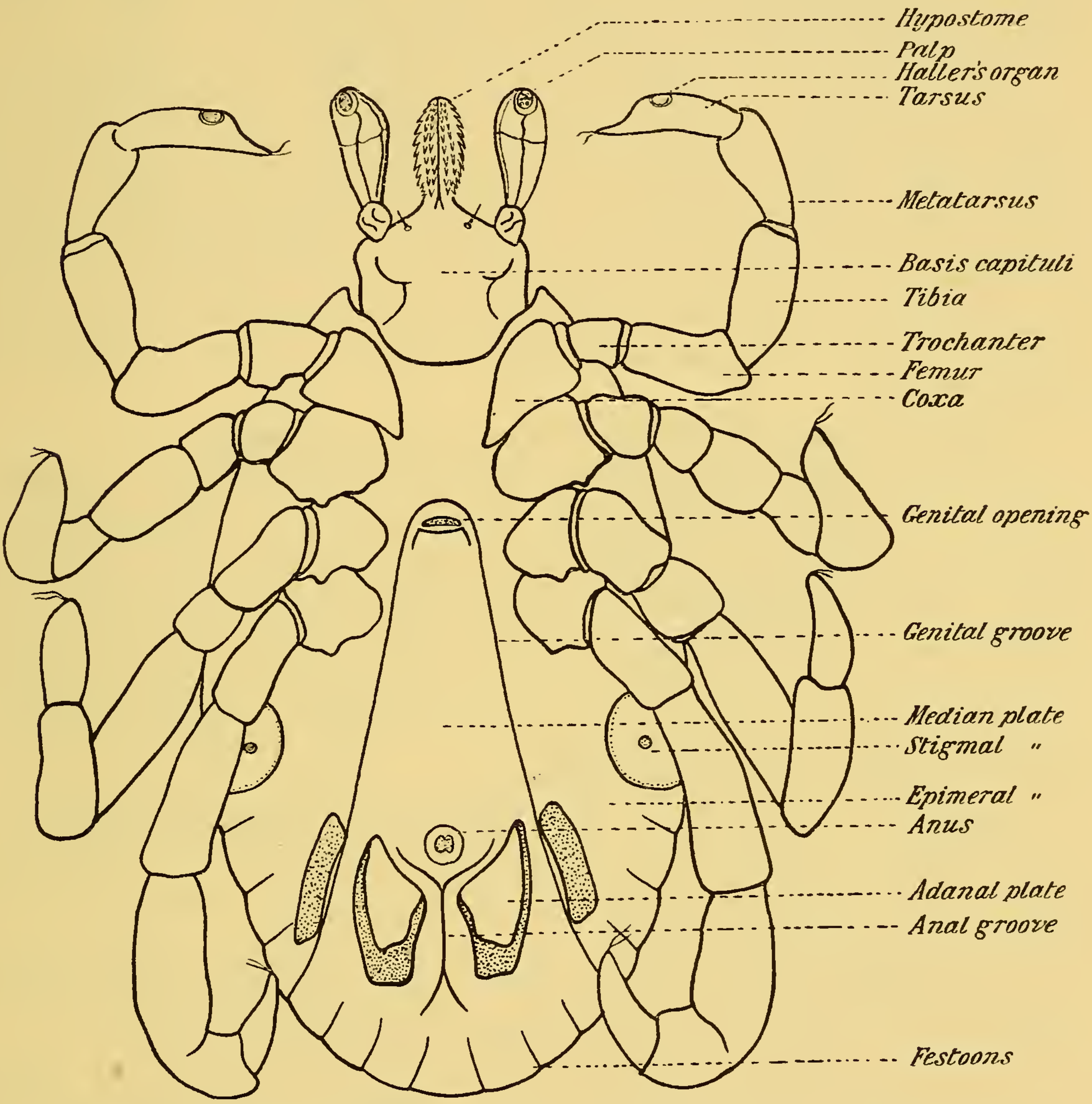



FIG. 24.—The Morphological Features of a Hard Tick. (Ventral view.)

or polygonal plate whose ventral surface is somewhat convex; this plate is the **basis capituli**; its dorsal surface bears in the female a pair of median areas perforated in sieve-like fashion and regarded as sensory.

The basis capituli bears (*a*) a pair of finger-like **pedipalps,** consisting of three large joints with a small fourth joint on the dorsal surface of the third; the pedipalps are sensory structures. (*b*) A pair of **cheliceræ,** each of which consists of a straight shaft

which bears a movable terminal digit, an irregularly-shaped piece of chitin articulating with the end of the shaft and having two movable joints each armed with teeth ; the cheliceræ are covered dorsally by a sheath formed by an extension of the cuticle of the basis capituli. (*c*) A median **hypostome,** a poker-like structure consisting of two closely opposed halves armed with backwardly directed teeth ; this hypostome, which is not visible in dorsal view, is the real piercing organ.

The mouth lies between the cheliceræ and the hypostome.

The body bears on its ventral surface four pairs of legs which have large coxæ or basal joints ; a pair of stigmatic plates each perforated by a respiratory aperture and lying behind the last pair of coxæ ; a genital opening in the middle line, not far behind the capitulum ; an anal opening, a little way from the posterior edge ; and in some ticks prominent grooves round the genital aperture and anus, the *genital* and *anal* grooves.

The ticks may be grouped into two sub-families.

The **Argasinæ** or Soft Ticks are flattened, or rounded ticks with a somewhat soft, flabby body, and with the capitulum invisible from above. They do not remain on the host for longer than it takes them to gorge themselves with blood, but usually spend the daylight in crevices somewhere in the vicinity of the host animal, and come out at night in order to find a host individual upon whom to feed. There are two genera, namely, **Argas** and **Ornithodorus.**

**Argas** has a flattened oval body with a thin striated edge.

Its eight species are particularly parasites of birds, and infest the nests and houses of fowls, ducks, geese, turkeys, pigeons all over the world.

*A. persicus* carries the spirochæte of fowl cholera, *Spirochæta gallinarum*, and seems to be a true intermediate host of it.

The other genus, **Ornithodorus,** is distinguished from *Argas* by its rotund, wrinkled body. *O. moubata* is common in African villages, and in addition to its power of inflicting a very painful bite, is the intermediate host of *Spirochæta duttoni*, the organism of African relapsing fever.

The **Ixodinæ** or Hard Ticks are characterised by the hardening of the dorsal surface of the body to form what is termed a *shield.*

In the male tick the shield covers almost the whole dorsal body surface, but in a female or an immature tick the shield only covers a portion of the dorsal body surface.

The usual life history is somewhat as follows. The eggs are

laid on grass or herbage and may take two to six months to hatch. The larva has only three pairs of legs. It has to search

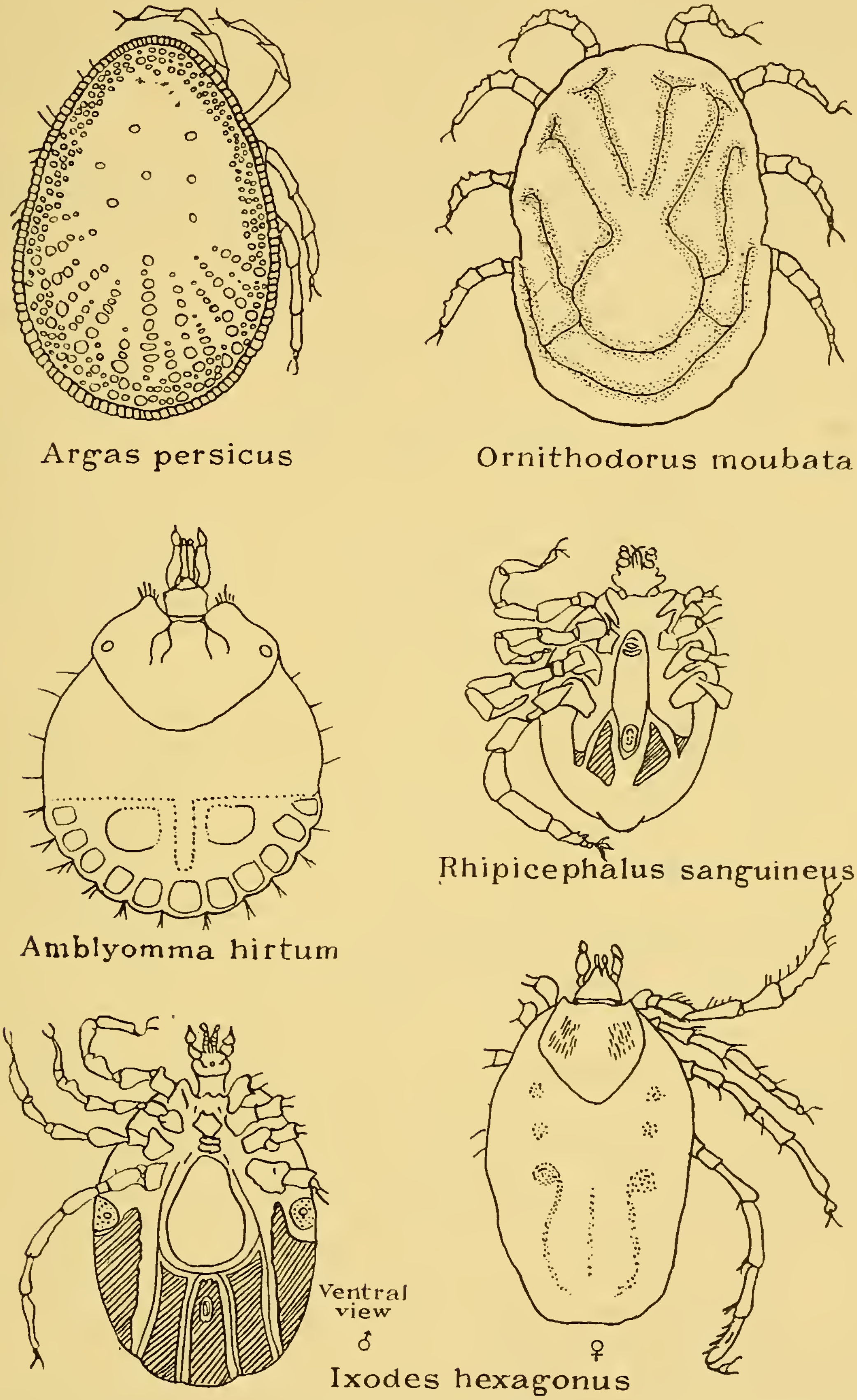



FIG. 25.—Types of Soft Tick and Hard Tick. (After various Authors.)

for a host animal upon which to feed. After a few days on the host it is gorged and it falls to the ground. Here it moults, and the moulted form now possesses four pairs of legs, but as it lacks still the genital opening, it is termed a nymph. This

again has to find a host upon which it can gorge itself, and again, after gorging, it must come to the ground in order to moult and to mature. The adults copulate on the ground, and the fertilised female must again seek out a host, must again gorge herself with blood, and must again come to the ground in order to lay her eggs.

Usually the number of eggs laid by a Hard Tick is large, from 5,000 to 20,000 ; this counterbalances somewhat the very slender chance that any individual larva possesses of completing its life-cycle. It must be noted that the larval tick or " seed tick," as it is popularly termed, may have to hang about on the tip of a blade of grass for weeks or months before a host animal comes along. In the majority of ticks it is not usual for the larva to go in search of a host, as is done by those of Soft Ticks. Further, even if a host be secured for the larval period of the life history, this host must be left, and the chances of the nymph securing a host are as slight as those of the larva. Even if successful, this host again must be left and eventually another host animal secured.

On the whole, therefore, the odds against any tick successfully completing its life-cycle are very heavy ones.

All tick stages, however, are extraordinarily resistant to lack of food. Larvæ have been known to live six months without food ; adults can be kept alive in corked tubes for five years. Further, when a host is attacked, the tick usually secures itself in some position such as the interior of the external ear, where its feeding is not likely to be interrupted.

In some species, the risk involved by leaving a host animal in order to moult is to some extent minimised by the tick remaining on the host from larval to adult stage, as is done by *Margaropus annulatus* ; in others, the first moult is spent on the host, but the rest of the moults are spent on the ground.

The importance of ticks in the transmission of disease concerns the veterinarian more than the medical practitioner.

Two classes of diseases are associated particularly with ticks, namely, spirochætoses and babesioses. These diseases have been discussed in Chapter IV.

Rocky Mountain spotted fever of man, prevalent in the Rocky Mountain states of North America, and caused probably by an invisible virus, is almost certainly conveyed by ticks, probably by *Dermacentor andersoni* and *Hæmaphysalis leporis-palustris.*

# PART II

# AGRICULTURAL AND HORTICULTURAL ZOOLOGY

## CHAPTER XIII

## SOIL ORGANISMS

The term *soil organism*, referring as it does to any living creature whose whole life-cycle is spent within the surface layers of the soil, can be applied to a very wide range of animal organisms.

It is applicable to a very large number of protozoa, for example; to a number of genera belonging to the nematode family Anguillulidæ; to those families of segmented worms to which the popular term "earthworm" is applied; to those families of molluscs termed "snails and slugs"; to a large number of insects and arachnids; even to certain soil-burrowing vertebrate animals.

In addition, there is a wide range of protozoa, flatworms, nematode worms, and insects which, if not soil dwellers exclusively, spend some portion of their life-cycle within the surface layers of the soil.

In this chapter, discussion of soil organisms will be confined to two groups of animals, the soil protozoa and the earthworms, whose activities bear upon the question of soil fertility; and to certain groups which are directly inimical to the plant grower, notably the eelworms, slugs, termites, ants, and certain types of insect larvæ.

**Soil Protozoa.**—The presence of protozoa in the soil, together with fungi, algæ, bacteria, and worms, was demonstrated by Ehrenberg so far back as 1837, but the possible economic significance of Soil Protozoa only came to light between 1909 and 1913, when Russell and Hutchinson propounded what may be termed a Protozoan Theory of Soil Fertility, an explanation, in terms of protozoan metabolism, of the well-known fact that, when soil is partially sterilised by heat or by chemicals, it can produce a greater yield of crops than it did before.

The soil used by Russell and his collaborator was taken from an arable field and contained moderate but not large amounts of calcium carbonate, nitrogen, and organic matter. It was partially sterilised by heating to 98° C. or by adding 4 per cent. of its volume of toluene ; when toluene was used it was allowed to act for three days, after which time the soil was spread out in a thin layer so that the bulk of the chemical would evaporate.

Speaking generally, such treatment of soil enables it to produce a greater yield of non-leguminous crops than untreated soil is capable of doing.

There is an increase in the amount of soil ammonia, a fact which suggests that partial sterilisation removes some inhibiting agent which in normal soil restricts bacterial reproduction and ammonia formation. Russell and Hutchinson, after excluding the possibility of the restricting agent being chemical rather than biological, definitely concluded that the factor inhibitive to ammonia production in normal soil is the presence of protozoa predatory upon soil bacteria.

This view requires, of course, the assumption that, under natural conditions, there is an equilibrium between the saprobiotic soil organisms, such as ammonia-producing bacteria, and the protozoa which prey on them, so that the rate of ammonia production in untreated soil neither increases nor decreases very greatly. If, however, the soil be subjected to thermal or to chemical influences sufficiently intense to kill the free-living bacteria and the protozoa, both free-living and encysted, but not so intense as to kill bacterial spores, then the flora which ensues from the surviving spores will multiply with great rapidity owing to the absence of restrictive agents, and consequently there will be an increase of ammonia production and subsequent increase in crop yield. If, however, the soil be completely sterilised so that bacterial spores as well as protozoa are destroyed, there will not be, of course, any marked increase in fertility. The work of Russell and Hutchinson gave a very great impetus to the study of soil fertility, and during the last ten years an enormous amount of experimental work has been carried out upon the question of soil sterilisation.

It may be asserted that many facts have come to light which appear to support the Protozoan Theory, but that there are very many facts which appear to controvert it. In fact, this theory is not accepted by the majority of investigators in the subject.

Alternative explanations look to a chemical or to a physiological cause of the increased productivity of partially sterilised

soils. The following are the main alternative suggestions that have been put forward:—

(*a*) Heating destroys toxins present in untreated soils; such toxins have been produced by the plants or by bacteria.

(*b*) Heating leads to the formation of a nitrogenous compound whose presence brings about an increase of soluble nitrogenous matter in soil; soils treated with carbon bisulphide, chloroform, ether, benzene, and so on, undergo a chemical change which increases the amount of soluble nitrogen.

(*c*) Partial sterilisation has a selective action upon the ammonia-producing bacteria; such as survive belong to groups which are more active decomposers of organic matter than are other groups, and so the amount of ammonia increases. This last view has received much support.

Whilst probably, as Russell and Hutchinson assert, bacteria after partial sterilisation are less potent as individuals, and the increased ammonia production is due solely to the numerical increase, yet it is well known that various groups of bacteria differ from one another in their power to produce ammonia; thus *Bacillus mycoides* is a better ammonifier than *Bacillus subtilis*. It remains to be established how each of the various groups of soil bacteria is affected by partial sterilisation.

It must be noted, too, that partial sterilisation does not necessarily destroy all fungus spores, and that many species of fungi, *Cephalosthecium roseum*, for example, can produce considerable quantities of ammonia.

The predominant protozoa in soil, as regards variety of species, are Mastigophora; possibly many of these are not distinct species at all but are stages in the life-cycles of amœbæ; the commonest protozoa, numerically, are certain ciliates, particularly *Colpoda cucullus* and *Colpoda steinii*.

The more important protozoan species after these two are:—

MASTIGOPHORA.—*Monas guttula*, *Monas vivipara*, *Salpingœca concullaria*, *Bodo ovatus*, *Bodo augustus*, *Bodo caudatus*, *Phyllomitus undulans*, *Bodo euromonas*, *Euglena viridis*, *Polytoma uvella*, *Chlamydomonas*, *Monadina*.

CILIATA.—*Nassula elegans*, *Glaucoma scintillans*, *Colpidium*, *Colpoda*, *Balantiophorus minutus*.

Cutler gives the following list as common in Rothamsted soil:—*Nœgleria gruberi*, *Heteromita sp.*, *Cercomonas sp.*, *Oicomonas termo*. Less numerous are *Amœba glebæ*, *Amœba verrucosa*, *Hartmanella hyalina*, *Arachnula impatiens*, *Difflugia sp.*, *Copromonas subtilis*, *Spiromonas augusta*, *Tetramitus rostatus*, *Tetramitus spiralis*, *Helkesimastix fœcicola*, *Phyllomitus*

*amylophagus*, *Optidomonas sp.*, *Bodo edax*, *Colpoda steinii*, *Colpoda cucullus*, *Colpidium colpoda*, *Pleurotricha*, *Gastrostyla sp.*, *Balantiophorus sp.*, *Euchelys sp.* All these protozoa are typical members of stagnant pools, and are not peculiar to the somewhat more precarious environment of moist earth.

There is both a daily and a seasonal fluctuation in the numbers of soil protozoa. The numbers of individuals of one species may vary from a few hundreds per gram of soil to 40,000 or more within twenty-four hours.

The soil population reaches a maximum at the end of November in Great Britain, and falls to a minimum at the end of February. The reason for these fluctuations is not clear. It has not yet been found possible to connect them with meteorological or general soil conditions.

**Earthworms.**—According to Charles Darwin's classical work upon the influence of earthworms in converting vegetable mould into plant food, some ten tons of soil per acre are passed annually through the bodies of earthworms on an English farm.

The quantity of soil per acre thus made use of by earthworms will vary, however, according to the number of worms present in an acre of land, and this number will vary according to the quality of the soil.

On manured farm land in Great Britain the number of worms may exceed one million per acre, whereas in adjacent unmanured land the number may be below half a million. In an acre of soil from 200 to 1,000 lbs. weight of worms may occur, belonging chiefly to the genera **Lumbricus, Allolobophora, Eisenia,** and **Helodrilus.**

The food of earthworms comprises not only plant residues but soil organisms, algæ, fungus mycelia, yeasts, and so on. Earth is passed through the alimentary canal, the contained organic matter is decomposed, and the finely comminuted soil, containing nitrogenous waste matter, becomes deposited as castings at the surface of the burrows. There is thus a continual ascent of sub-surface soil to the surface in consequence of earthworm activity, and there can be little doubt that soils containing earthworms will contain a higher ammonium content than will soils in which earthworms do not occur.

The chief value of earthworms, however, arises from their action in loosening and mulching the soil, and in facilitating aeration and drainage by their burrowing habits.

In moist soils, especially if rich in organic matter, the earthworms present include large numbers of small white forms belonging to the family **Enchytræidæ,** and comprising chiefly species of **Fredericia** and **Enchytræus** and **Anachæta.**

**Soil Nematodes.**—The majority of soil nematodes belong to the family *Anguillulidæ* or eelworms, a family of minute worms characteristic in the fauna of decaying organic matter. Their abundance in the soil depends upon conditions of moisture and the occurrence of plant life or of decaying organic matter or of other micro-organisms. Their mode of nutrition varies considerably.

(1) They may be omnivorous, feeding upon living bacteria, fungi or algæ, or upon the bodies of such forms, or upon the organic matter in process of decomposition by such forms. This group includes the genera **Rhabditis, Diplogaster, Cephalobus, Dorylaimus, Plectus, Monohystera,** all common and cosmopolitan in distribution.

(2) They may be partly free-living, partly parasitic on animals and plants. The genera **Tylenchus, Heterodera,** and **Aphelenchus** are notorious pests, for example, of cultivated plants.

(3) They may be predaceous upon other eelworm species. This is the case with the very common eelworm **Mononchus,** which readily attacks other forms, either swallowing them outright or sucking out their contents. As many as eighty-three *Heterodera radicicola* have been observed to be killed in one day by a single *Mononchus* individual.

**Tylenchus** is a genus occurring in peaty and in moist soils and around the roots of plants. Certain species are of considerable economic interest. **Tylenchus dipsaci** attacks a great variety of plants, including clover, oats, rye, onions, tomatoes, tulip bulbs. It confines its attack to the lower portion of the stem of the attacked plant, never attacking the roots, and hence is usually termed the "stem eelworm." In the swollen portion of the stem occur large numbers of minute worms not exceeding 1 mm. in length, each provided with a chitinous mouth spine and two œsophageal swellings. The female produces oval eggs within the invaded plant tissue. The larval stages pass into the soil when the swollen stem portion decays and can remain there in an encysted coiled condition throughout the winter. They attack the plant seedlings in early spring usually, autumn sown plants rarely suffering. Remedial measures should comprise deep ploughing in autumn so as to bury the top eighteen inches of soil, the avoidance of crops which are liable to attack, and the avoidance of stable manure which, in an infected district, is a fruitful cause of infection. **Tylenchus scandens** attacks wheat. The young larvæ make their way from the soil to the nearest rootlings of seedling wheat plants, and bore between leaf, sheath, and haulm. They gradually climb higher up the growing plant to the future ear, bore each

into an ovule, and produce a purple gall formation within which occur thousands of larval stages. In an infested plant sixteen to twenty such purple "ear cockles" occur in the lowest flower of the ear, ten to twelve in the next, four to five in the top blossoms. Within the gall the larvæ are said to survive desiccation for as long a period as twenty years, but when the gall is moistened, as by falling upon damp earth, the larvæ can emerge, make their way to a young wheat plant, and attack it.

**Heterodera schachtii** attacks the sugar beet, potato, etc., and sometimes proves very injurious. Unlike most eelworms, there is marked sexual dimorphism in this form, the female being lemon shaped and fixed to a rootlet of the attacked plant. The swollen condition of the female is due to the fact that the eggs develop within her, and the larvæ are liberated by the death and disintegration of the female parent. The larvæ bore each into a rootlet of the beet and produce swellings upon it. The male larvæ coil up spirally, undergo a resting stage followed by a shedding of the cuticle and a migration into the soil, in order to seek the female individuals on the root swellings, who have meanwhile become exposed by the rupture of the swellings which enclose them.

**Caconema radicicola,** the "root knot nematode," produces knot-like swellings along the roots of tomatoes, cucumbers, marrows, cotton, beans, celery, egg plant, potatoes, lettuce, peas, and many other plants. The eelworms swarm within these galls and escape when the plant root decays, to pass into the soil and attack other plants. Soil may remain infested with resting eelworm stages for a long time and may require partial sterilisation.

**Aphelenchus** comprises a number of forms which occur around the roots of plants in moist humus or in water. Five species are recognised as being distinctly injurious, namely, *A. fragariæ*, which is endoparasitic in the stem tissue of strawberry plants, producing a hypertrophic condition termed "cauliflower disease," or ectoparasitic in the strawberry buds; *A. cocophilus*, endoparasitic in stem, leaf, and roots of the coconut palm in West Indies, and causing "red ring" disease, so called from the characteristic internal ring of red tissue developed in the stem of the plant attacked; *A. ritzema bos*, endoparasitic in the leaves of chrysanthemums; *A. ribes*, ectoparasitic in the buds of the black currant; and *A. olesistus*, endoparasitic in the stems of ferns, begonias, and cypripediums, causing destruction and discoloration of tissue; *A. olesistus* var. *longicollis* attacks the stems of cultivated violets, causing hypertrophy and gall formation.

The only effective remedy for eelworm disease is soil sterilisation, but sterilisation measures are usually impracticable except in glass houses. Some machine is required that can be wheeled over a field like a plough and which will automatically lift up the surface layers and submit them to a temperature sufficient to sterilise the soil, but such machinery is still in the experimental stage.

**Soil Insects.**—The insects which frequent the surface or subterranean layers of the soil may be grouped, according to food habit, into :—

(1) Insects which find food and shelter within the soil layers. This group includes phytophagous insects, such as in particular those larval forms referred to as white grubs, as leather jackets, as wireworms ; zoophagous insects, such as the carnivorous Carabid and Staphylinid beetles, and certain carnivorous larvæ of the two-winged flies ; and saprophagous insects, such as are the Collembola, and the majority of soil-dwelling larval forms of flies and beetles.

(2) Insects which find shelter within the soil layers but feed on the surface vegetation. This group includes particularly the termites and the ants, but is linked up to the first group particularly by certain forms of termites which are always subterranean feeders and by the cutworms or Noctuid caterpillars, some of which are surface feeders, sheltering in the soil when not feeding, others of which are sub-surface feeders.

(3) Insects which spend a phase of their life-cycle within the soil, either as internal parasites of soil insects or as resting, non-feeding pupal stages, or again as hibernating or æstivating, non-feeding stages.

The number of insects in the soil is very large, and is distinctly larger in samples of uncultivated soil than in samples of cultivated soil. Morris at Rothamsted has recorded 3,586,088 insects in an acre of permanent pasture, a number comprising Collembola, 566,680 ; Rhynchota, 15,140 ; Thysanoptera, 43,258 ; Lepidoptera, 15,140 ; Coleoptera, 744,038 ; Diptera, 2,193,180 ; Hymenoptera, 8,652. The family most represented was the Bibionidæ, whose species made up 32·4 per cent. of the total number of soil insects ; Mycetophilidæ made up 16·7 per cent. ; and Staphylinidæ made up 12·2 per cent.

The fauna of cultivated land is not, as a rule, peculiar to such land, but is made up of migrants from adjacent woodland or grassland.

From the standpoint of the crop grower, the more important types of soil insect are certain larval types referred to as white

grubs, leather jackets, wireworms, cutworms, and certain social soil insects known as white ants or termites.

**White Grubs.**—The term white grub applies to the larvæ of chafers or May beetles, a sub-family of beetles included in the Scarabæidæ or Sacred Beetles. The adult chafer is a clumsy, dull-coloured insect which feeds upon the flowers and foliage of plants ; the grub is a white fleshy curved creature with a somewhat swollen posterior segment and very short legs ; it is a voracious feeder upon the roots of plants (Fig. 26).

The eggs are laid usually in early summer, or, in tropical countries, at the commencement of the rainy season. Usually grassland in the vicinity of timber is preferred. The eggs are enclosed within a ball of cemented earth particles and placed below the soil surface. The emerging larvæ feed upon the roots of adjacent plants until the onset of cold or of dry conditions forces them to migrate downwards, sometimes to a depth of six feet. The winter or dry season is thus spent as a non-feeding, deeply buried larval stage. In the spring the larva ascends to near the surface and feeds voraciously through the summer, descending again when soil conditions become unfavourable. The second spring sees the larva again near the soil surface, but usually in the second summer the larva pupates within an earthen cell about two feet below the soil surface. The pupa transforms into the beetle stage before winter, but the insect remains within the soil until the following spring, thus completing a three-year cycle. In many cases the cycle is four or five years in length. In favourable latitudes, however, it is only two years or even one year in duration.

In Europe great damage is caused, particularly in forested areas, by enormous numbers of the cockchafer (**Melolontha vulgaris** and **Melolontha hippocastani**), which feed as adults upon the foliage of oak, elm, etc., and as larvæ upon the roots of grasses and seedling trees. Similar but lesser damage is caused also by species of **Anomala** and **Phyllopertha.** In North America, species of **Phyllophagus** (*Lachnosterna*) constitute a limiting factor to continuous wheat production in certain sections, the infestation increasing with each generation so that rotation with an unfavoured crop, such as rye or oats, becomes necessary. Little direct action is possible against white grubs. They are well below the plough line during the usual ploughing season. If, however, severely infested grasslands be ploughed during the summer, large numbers of eggs, larvæ, and pupæ become exposed and are eagerly sought for by birds, especially poultry, rooks, crows, and crow-blackbirds.

Certain mammals, also, notably hogs and skunks, will seek and devour white grubs with avidity, and it may be noted, as some

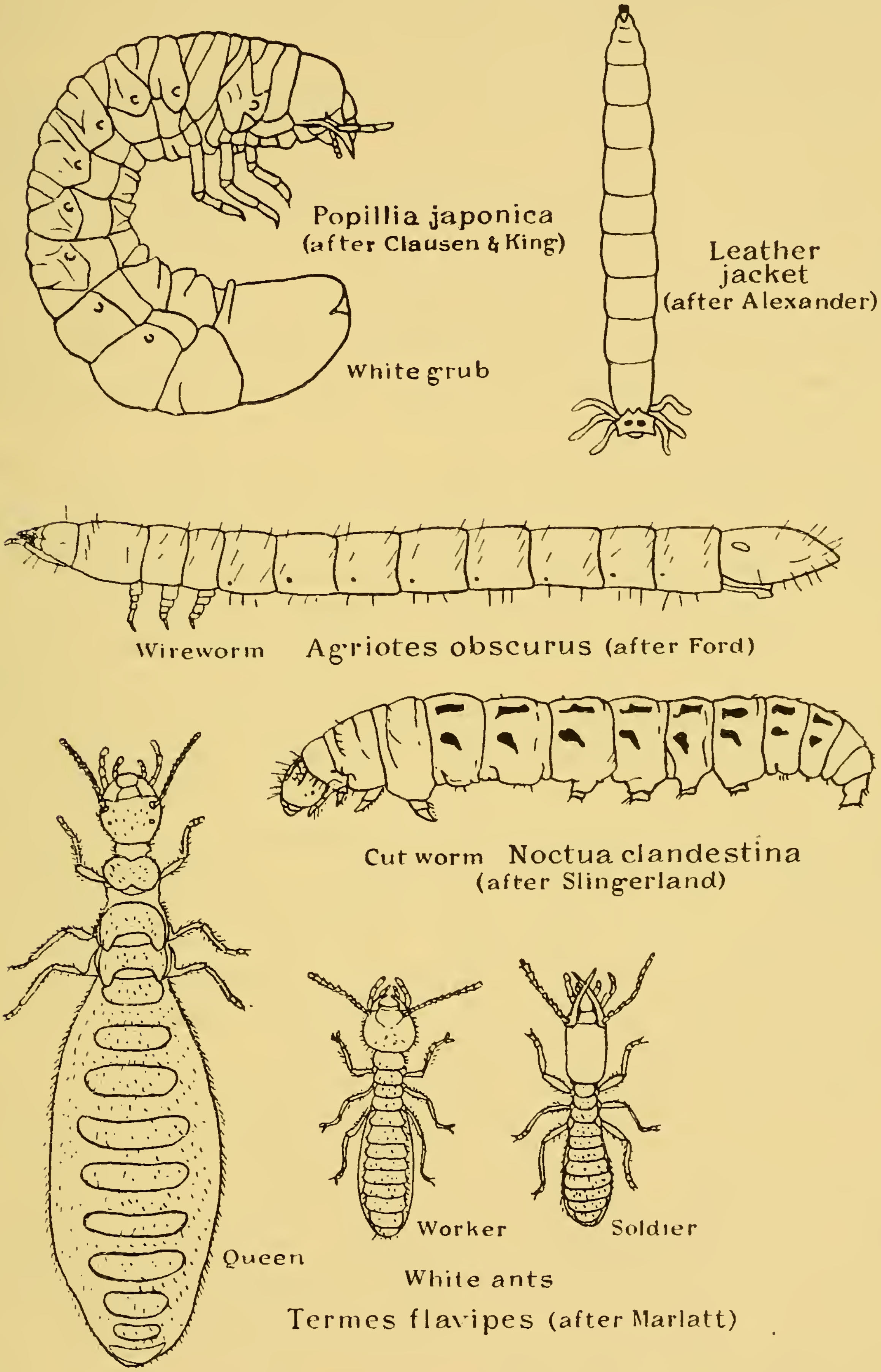



FIG. 26.—Types of Soil Insects. (Not to scale.)

evidence of the antiquity of the taste shown by the hog for white grubs, that in Europe the invertebrate host of a parasitic

worm, *Echinorhynchus gigas*, found in the hog, is the white grub of the cockchafer.

**Leather Jackets.**—The leather jacket is the larval stage of a crane-fly, which again is a type of two-winged fly belonging to the superfamily Tipuloidea.

Only a minority of crane-fly larvæ are injurious to cultivated crops, and these are usually species of **Tipula** or **Pachyrhina.** In temperate latitudes considerable endemic annual damage is produced by the attack of leather jackets upon the roots of vegetation in grassland, root-crop or cereal-growing areas, although, owing to the work of insectivorous birds and mammals, epidemic outbreaks of leather jacket damage are rare.

In circumscribed areas, such as golf courses, crane-fly damage can be reduced considerably by the use of arsenically poisoned bran baits.

**Wireworms.**—The wireworms are larval stages of the "click beetles" (Elateridæ), and are, in the main, grassland pests, although such crops as potatoes, root crops, cereals, suffer greatly. In many respects their habits are like those of the white grub, in that they live underground and attack the planted seeds, roots, and underground stems of cultivated plants, and in that they remain in the ground as larval stages for four or five years. In appearance, however, the wireworm is a cylindrical yellowish-brown hard larva from one-half to one and a half inches long (Fig. 26). The injurious wireworms belong in particular to the genera **Agriotes, Athöus, Limonius, Melanotus,** and **Ludius** (*Corymbites*). Wireworms are, in particular, pests of newly cultivated grassland rather than of land that has been cultivated over a period of years. One common control method is that of using mustard as the first crop upon newly broken grassland, and ploughing this crop under before sowing the first cereal crop.

**Cutworms.**—The term cutworm applies generally to caterpillars of the Noctuidæ family of moths, but should be restricted to caterpillars of the sub-family *Agrotinæ.* The moths are usually coloured dull grey or brown and are night-flying in habit. The caterpillars are mainly smooth, protectively coloured in brownish or dull green patterns, and generally nocturnal in feeding habit, hiding by day in the surface soil layers (Fig. 26).

The cutworms fall into three groups according to habit, namely :—

(1) **Climbing cutworms,** which actually climb up the plant and eat the foliage rather than the stem.

(2) **Surface cutworms,** which feed at or just above the surface of the ground and cut off the stems of plants.

(3) **Sub-surface cutworms**, which feed entirely below the soil surface and cut the plant from one to two inches below ground. This is a comparatively uncommon habit, but is shown in particular by the Pale Western Cutworm (*Porosagrotis orthogonia*), a notorious pest of the north-western states of North America.

The cosmopolitan cutworm species, such as the species of *Agrotis* and *Euxoa*, are surface feeders as a rule.

Surface caterpillars are controlled by the use of poison baits or by the use of stomach poisons applied to the food plant.

**Termites.**—Termites or white ants are members of the insect order Isoptera. The term " white ant " is not a very suitable one. Their affinities with the ants are remote. Like ants and bees and wasps, however, termites are social and live in large communities which are polymorphic, that is to say are made up of several structurally different types or castes.

In a typical termite community five such castes occur, three of which are potentially reproductive, the remaining two being composed of sexually sterile individuals (Fig. 26).

These castes are as follows :—

(*a*) **Macropterous forms,** provided with well-developed cuticle and with two pairs of well-developed wings. At certain times of the year, varying with geographical locality, dense swarms of winged males and females will issue from a termite colony. The great majority of the individuals of the swarm fall a prey to numbers of birds, lizards, even small mammals, which are attracted by the phenomenon. The survivors eventually come to the ground, cast off their wings, copulate, and found a new colony, in which the initial pair becomes the king and queen. The queen gradually increases in size, owing to the development of her ovaries, and may become comparatively enormous. The pair live secluded in a special royal cell.

(*b*) **Brachypterous forms,** with short, scale-like wings, weak eyes, and thin, yellowish transparent cuticle. The part played by these forms in the community is not fully known, but that they are capable of providing substitutes for the reigning royalty, if required, seems very probable.

(*c*) **Apterous forms,** without wings, with vestigeal eyes and with a weak transparent cuticle. The conditions under which these forms occur and utilise their reproductive powers are not understood. They are rarely found among the higher termites. The two remaining castes are sexually sterile.

(*d*) **Workers** form the great majority of the individuals in

the community and carry out most of the work of the colony, whether tending eggs and young, feeding and tending royalty, excavating galleries, bringing in food, and so on. They are wingless, blind, and have a thin cuticle, but the jaws are powerful and well adapted to the crushing of woody tissue.

(*e*) **Soldiers,** like the workers, are blind, wingless, and sterile, but characterised by possessing a powerfully developed head; in the *nasute* type of soldier the head projects forwards as a conical snout-like structure, and the jaws are small and vestigeal; in the *mandibulate* type the head does not so project, and the jaws are powerful and large. In some cases both types may be again separated into major and minor forms, or even into large, intermediate, and small forms, according to size.

The soldiers are concerned with defence of the colony; their capacity for dealing with intruders is aided by the power in some forms with weak jaws of supplementing the use of their jaws by the ejection of a repellent fluid, through a pore at the tip of the snout-like projection.

The habits of termites vary considerably in detail, but the food in all cases is primarily wood and other vegetable tissue, the cellulose in their diet being dealt with, according to some authorities, by certain commensal, gut-dwelling flagellate protozoa which are peculiar to termites and which, by breaking down cellulose, are possibly of considerable benefit to their host. In young nymphs and in royalty they are said not to occur, and it is significant that these termite forms have to be fed by the workers with a special diet.

Three types of termite community may, speaking generally, be distinguished, namely :—

(1) Colonies occurring as a series of galleries in woody plants, either in decaying fallen logs, in actively growing trees and bushes, or in worked timber such as furniture, wooden buildings, telegraph posts, and the like.

(2) Colonies occurring in labyrinthine nests below the ground surface; from such colonies the workers issue forth to attack the roots of growing plants, or to tunnel in any woodwork that is in contact with the ground; when working above ground they usually construct covered passage-ways of earth or fæcal matter so that they can travel without annoyance from sunlight, sun heat, desiccation, or predatory enemies.

(3) Colonies which occur as a network of galleries within a mound of soil cemented together by salivary secretion; these mounds are a prominent landscape feature in Africa and Australia, and may be from six to twenty feet in height and as hard as concrete.

The prevalence of termites in tropical and sub-tropical soils, their subterranean and social habits, and their preference for woody tissue causes them to be amongst the most stubborn enemies of the tropical agriculturist. Crops and habitations are alike endangered by termite colonies.

Speaking very generally, measures against termites may be divided into offensive and defensive categories.

Offensive measures comprise :—

(1) The fumigation of nests or mounds with carbon bisulphide, or with a mixture of arsenic bisulphide and arsenic trisulphide and pentasulphide fumes, injected into the mound by the use of an ant exterminator. This machine consists in principle of an arrangement by which air can be blown over a mixture of arsenic trioxide and sulphur placed upon a bed of red-hot charcoal, and the resulting vapour forced into the termite nest through a tube.

(2) The addition of a slight percentage of kerosene to irrigation water.

Defensive measures comprise :—

(3) The use of concrete and metal as foundation materials for buildings, and of termite resistant timbers such as teak (*Tectonia grandis*), greenheart (*Nectandria rodiaci*), and mahogany, or of timbers proofed with termitifugal chemicals, in building construction. Books, leather, small wooden articles must be proofed with corrosive sublimate, zinc chloride, or similar substances of known repugnant effect upon these insects.

**Ants.**—Speaking generally, ants do not constitute a menace to the agriculturist. Certain ant species, however, which cultivate plant lice and scale insects for the saccharine secretion produced by these insects, may help considerably in spreading such plant-attacking insects throughout an agricultural district. A case in point is afforded by the Citrus Mealy Bug (*Pseudococcus citri*), a citrus pest of world-wide distribution. In Southern California the mealy bug is protected by the Argentine Ant (*Iridomyrmex humilis*), and it has been shown that in orchards where the ant has been kept in check by poison baits, the mealy bug has been distinctly checked by natural enemies.

Leaf-cutting ants may cause considerable damage to cultivated plants in tropical and sub-tropical countries. House-frequenting forms such as *Monomorium*, the small black house ant, and *Iridomyrmex*, the Argentine ant, can also be of considerable annoyance to man. Measures against ants comprise the fumigation or the destruction of nests, and the destruction of foraging ants by the use of syrups poisoned with sodium arsenite.

## CHAPTER XIV

### INSECT PESTS : The Categories

THE insect pests of the world's crops may be classified according to their wideness of distribution and severity of damage inflicted, or according to the type of agricultural product they attack, or according to the type of damage they inflict. Thus we may speak of First Class and Second Class Pests ; or we may speak of General Pests, Fruit Tree Pests, Truck Crop Pests, and so on ; or again we may speak of Cutworms, Moth Borers, and so on.

In the career of an insect pest certain phases occur. In the first place, it may have the status merely of a local insect and not that of an economically important species, and may enter, probably unobserved, a new territory. Immediately, the insect may find itself in a new environment, and consequently, even if its numbers do not suffer a severe check, its progress is necessarily slow. Later, its numbers begin to increase unduly, owing possibly to a lack or infrequence of natural enemies, and in about ten years time, or even less, it becomes noticeable in epidemic form. Should its habits be such as to annoy the community, it will be classed as a " Second Class Pest," that is to say, a pest severe in its infestation but confined to a limited area. At this stage vigorous control measures will probably check the insect, but should the infested article be a commercial commodity with a wide distribution, the chances are that the insect will have spread extensively and become well established before detection, or before there is anything approaching a full realisation of its economic significance. It will be, in fact, a " First Class Pest," and its extermination cannot be hoped for ; control measures in this case can aim only at limiting its spread and mitigating its ravages as far as possible.

It will be seen, therefore, that there are two main stages in the progress of an insect pest : firstly, when it is newly established or an indigenous pest within a limited area ; secondly, when it has become firmly established and is widely distributed.

Speaking very generally, the major pests of the world's crops can be placed into two groups.

The first group comprises insects which are **polyphagous,**

that is to say, which have a wide range of food plants and which are widely distributed over a wide continuous area where they cause steady endemic annual damage to crops. They are, however, liable to become massed in particular local areas and to become in consequence the cause of severe epidemic outbreaks, owing to their own powers of migration, to the agricultural practice of growing large contiguous blocks of some particular type of plant, or owing to dissemination by human agency. This group comprises the following types of insect pest, namely, locusts, red spiders, plant bugs, leaf hoppers, plant lice, thrips, flea beetles, weevils, noctuid caterpillars, loopers, tussock caterpillars. It also includes a considerable number of species of scale insect. The second group comprises insects which are **oliphagous** or **monophagous,** that is to say, restricted in choice of food plant, and which may be more or less restricted in distribution owing to some peculiarity of habit, such as, for example, that of attachment permanently to the host plant, or the habit of plant mining, gall-making, leaf rolling, and so on. Owing, however, to these same peculiarities of habit, this group of pests is peculiarly liable to become introduced into a fresh area of distribution by the agency of man. In such a fresh area the absence of its natural enemies will enable the insect species to increase to a degree unknown in its native habitat, and to become the cause of intensively severe outbreaks; on the whole, the worst cases of epidemic attack are those caused by insects of this second group imported into a fresh area.

The group includes particularly the scale insects, mining insects, blister mites, gall-making insects, and in it also may be placed the insects which infest stored products. The various types of insect pest can now be briefly discussed.

**Locusts.**—The term locust or hopper is one usually applied to the migratory phase of certain members of the Orthopteran family **Acridiidæ**; the term grasshopper refers more particularly to non-migratory phases, or to members of the family **Locustidæ.**

Both families consist of comparatively large insects which have the femora of the hind legs thickened and enlarged in adaptation to a leaping habit (Fig. 27). The Acridiidæ possess antennæ shorter in length than the body, and so are referred to sometimes as "short-horned grasshoppers" in contradistinction to the "long-horned grasshoppers" or Locustidæ, whose antennæ are longer than the body. The latter, again, differ from the Crickets (Gryllidæ) in that the horny first pair of wings slope downwards at the sides and are not flat above, except for a short space near the base.

All these forms are able to make some kind of noise as a love signal to the opposite sex, either by rattling the horny wings

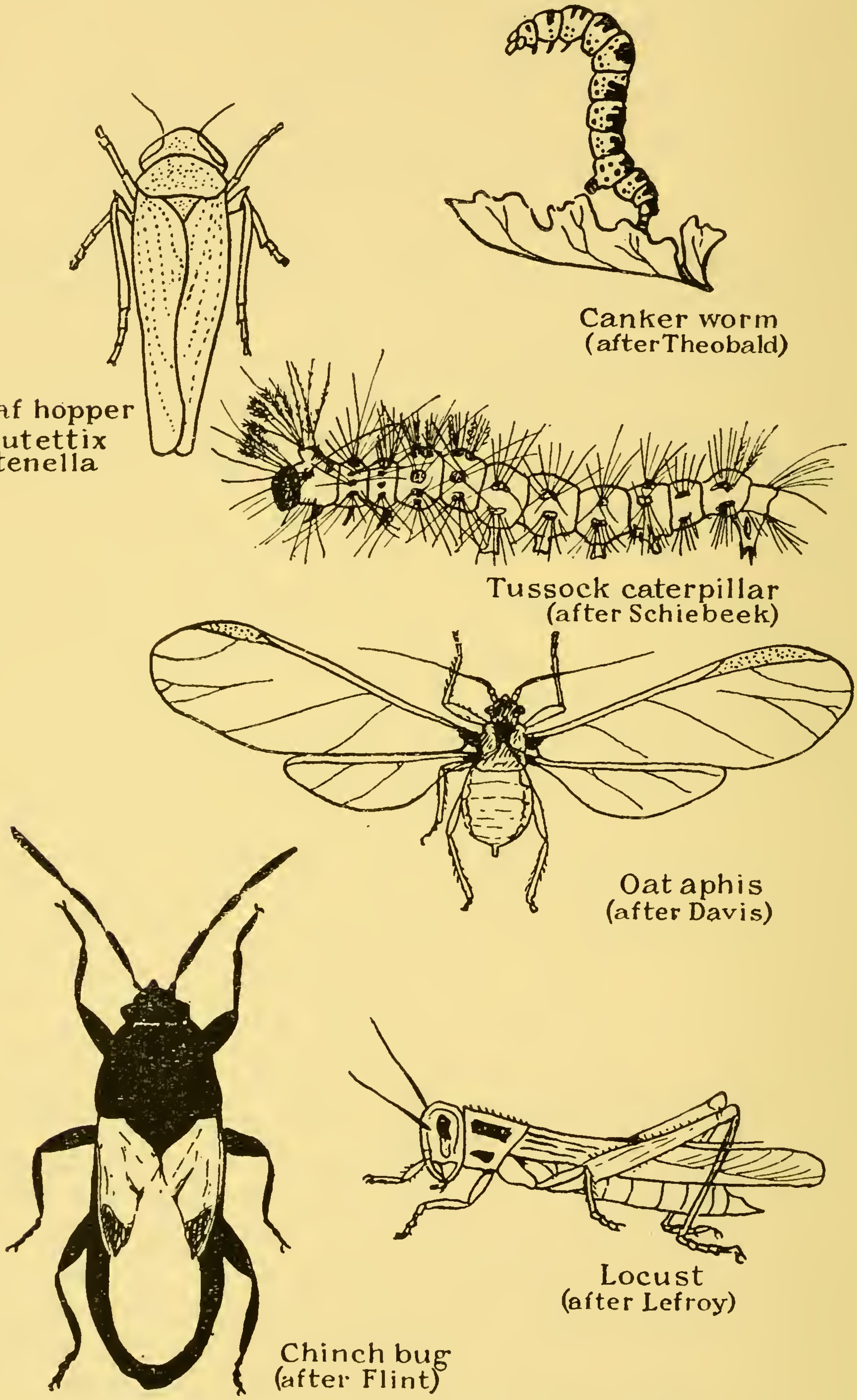



Fig. 27.—Types of Insect Pest. (Not to scale.)

or by rasping the hind legs against the horny wings or by rubbing one wing cover over the other. Acridiids have an

auditory organ on each side of the first abdominal segment; Locustids and Gryllids possess a similar organ on the foreleg.

The eggs are usually deposited in holes in the ground made by the valves of the ovipositor of the female. The eggs remain in the soil for a considerable period. A series of nymphal phases ensues, each nymphal phase resembling the adult form except in development of wings, which are absent or small, and in its immaturity. Hibernation or æstivation is passed, in most cases, in the egg stage.

Whether migratory or non-migratory these insects are extremely catholic in their choice of food plants, and are a potential source of damage to cultivated crops almost everywhere. Grasshoppers, crickets, and non-migratory locusts are endemic in every cultivated area, and are productive of steady annual crop loss, probably greatly exceeding in aggregate financial value the more spectacular ravages of the migratory phases.

Certain migratory forms characterise the majority of the great crop-raising areas of the world's surface. Thus Southern Europe and Asiatic Russia are periodically ravaged by migratory hordes of **Locusta migratoria**; Northern Africa by **Schistocerca gregaria**; South Africa by **Locusta pardalina**; Western India by **Acridium succinctus**; North-West India by **Schistocerca gregaria**; Canada and Northern United States by **Melanoplus spretus**; South America by **Schistocerca paranensis,** and so on.

In the control of a locust invasion, methods vary according to the area attacked; but on the whole the control measures comprise (1) the provision of barriers to the progress of the hopping stages, formed by trenches or by low metal fences; (2) the use of poison baits, mixtures of bran, or sawdust or horse manure or similar substances with Paris green—an arsenical compound—and made attractive by the addition of molasses, fruit juice, or amyl acetate; (3) the use of "hopper-dozers," a kind of trap drawn over the fields by a horse; (4) the artificial distribution of a bacterial disease of locusts.

**Red Spiders.**—The term "red spider" is applied usually to certain members of the arachnid family Trombididæ. That is to say, they are not insects at all in the strict sense, nor are they, for that matter, spiders.

They are extremely minute, rusty-red or green or even transparent creatures, provided with four pairs of legs.

The genus **Tetranychus** spins fine webs of silk upon the under surface of leaves; beneath these webs all stages of the pest are to be found sucking out the juices of the leaf.

**Bryobia** is a genus whose members do not spin webs; it

differs further from *Tetranychus* in that its members have the first pair of legs longer than the others.

Red spiders are extremely injurious foliage-sucking pests of a wide range of cultivated plants. On field crops they are extremely difficult to control. In greenhouses they can be checked by fumigation measures. In orchards, high-pressure spraying with water or with contact poisons or dusting with sulphur dusts will usually keep them within bounds.

**Plant Bugs.**—The term " bug," though applied often in the American sense to mean any sort of insect, is restricted by the entomologist to members of the Hemiptera, an order of insects which is characterised by the possession by its members of a suctorial beak in which the lower lip or labium forms a sheath for the needle-like mandibles and maxilla ; these are the actual piercing organs and these alone penetrate the tissues of the host plant. Usually two pairs of wings are present ; in the sub-order Homoptera, both pairs are thin and transparent ; in the sub-order Heteroptera, the anterior pair have the basal half thickened and horny.

The life-cycle consists of a series of stages termed *nymphs*, each differing from the preceding stages, and from the adult, only by the extent to which wings and reproductive organs are developed.

Plant bug is a term applied to members of the sub-order Heteroptera, and particularly to members of the families **Pentatomidæ, Coræidæ, Lygæidæ, Pyrrhocoridæ, Capsidæ.** The **Pentatomidæ** are usually referred to as Shield Bugs owing to the possession of a large *scutellum*, a term applied here to the dorsal portion of the thorax, anterior to the insertion of the first pair of wings. They are insects between a quarter of an inch and an inch in length, often brightly coloured, often protected by the foul smell from certain stink glands. *Nezara* is a notorious genus of injurious Pentatomid bugs. *N. viridula* is a green form common on potatoes all over the world.

*Murgantia histrionica*—the Harlequin Bug—is to the cabbage grower of the Southern United States what the boll weevil is to the cotton planter.

The **Coræidæ** or Squash Bugs are immediately recognisable by the small scutellum and straight beak, and by the insertion of the antennæ above an imaginary line from eyes to base of beak. *Leptocorisa varicornis* is a serious pest of the developing seeds of rice and millet in India. In the United States an allied species, *Leptocoris trivittatus*, is the Box Elder Bug. The Squash Bug, *Anasa tristis*, of the same area, is an evil-smelling

brown insect three-quarters of an inch in length, which infests pumpkins and squashes.

The **Lygæidæ** are similar in appearance to the Coræidæ, but on the whole are smaller forms. *Oxycarænus latus* and *Oxycarænus hyalipennis* are the Dusky Cotton Bugs of India and Egypt respectively, whose eggs are laid in the lint near the cotton seeds, and whose nymphs live within the boll, sucking the seeds, until adult.

Few insects have caused more pecuniary losses to the agriculturalist than has the Lygæid bug *Blissus leucopterus*, popularly termed the **Chinch Bug,** of the United States.

It is a native pest, supposed to have come from Central America previous to the settlement of the United States by the white man. It appeared first, in economic numbers, about the time of the Revolutionary War in North Carolina, the first place to grow wheat intensively. As the settlers moved westwards they disturbed the natural balance of the insect and introduced a plant upon which it could thrive. To-day it occupies practically the whole winter wheat belt. It requires, in order to become well established, suitable grasses on which to winter and a winter temperature not lower than 25° F.; sufficient rainfall (twenty to forty inches) through the year; suitable food plants, preferably wheat and corn, in the early summer.

These conditions are provided in the Central United States, notably in Kansas, Missouri, Illinois, Ohio, Indiana, and Nebraska.

In the north, winter temperatures keep it in check; in the east, excessive rainfall and the consequent spread of a fungus, *Sporotrichum globuliferum*, among hibernating forms, keep it in check; in the south and south-east, heavy rains and excessive summer temperatures and small acreage of wheat, limit its numbers; in the west, lack of suitable hibernation quarters and lack of summer rainfall militate against it.

It is a narrow black and white insect about one-fifth of an inch long (Fig. 27).

During the winter the bugs hibernate in clumps of grasses, particularly in prairie bunch grass, or in rubbish. The females emerge in spring and lay their eggs on the roots or stem bases of wheat or grasses. The resulting generation when mature migrates *on foot* to other plants, such as corn, upon which eggs are laid. There are thus two broods a year. Control measures comprise, therefore :—

(*a*) The destruction of grasses or rubbish in the vicinity of fields.

(*b*) The trapping of crawling bugs ; the time of migration is induced by the ripening of the wheat and its consequent loss of succulence. If the food supply holds out until the bugs are mature, they migrate both on foot and on the wing. Bugs migrating on the wing can neither be trapped nor destroyed. If the wheat ripens, however, or is cut before the wings have developed, the crawling bugs can be caught in large numbers in trap trenches or in a broad furrow six to eight feet wide of fine dust, or in a " tar line," a strip of smooth surface, about one foot wide, covered with tar or asphalt road oil. At intervals along the tar line, passages are left which conduct the bugs towards holes about a foot deep in which they are trapped.

The **Pyrrhocoridæ** or Stainer Bugs are scarlet or brown coloured bugs, recognisable further by the absence of ocelli and by the position of the antennæ on the sides of the head. The vivid coloration is possibly a warning coloration, since the bugs feed openly on their food plants. The genus *Dysdercus* is the so-called " cotton stainer," whose species occur in scarlet or brown masses on cotton plants in various cotton-growing areas. Thus *D. cingulatus* occurs in India, *D. suturellus* in the West Indies and United States, *D. superstitiosus* and *D. nigrofasciatus* occur in Africa.

The **Capsidæ** or Leaf Bugs are characterised by the possession of an area termed the *cuneus* at the base of each anterior wing. They are small, delicate, dull-coloured insects. *Helopeltis* is a genus destructive to tea, cacao, and cinchona in India and Africa. *H. theivora* is the notorious " mosquito blight " of the tea plant in Northern India. *Lygus pratensis*, the Tarnished Plant Bug, injures fruit and flower buds. *Lygus communis*, the False Tarnished Plant Bug, is a serious pest of hops in Great Britain. *Plesiocoris rugicollis* is a serious pest of apple trees in Europe.

**Leaf-Hoppers.**—The term leaf-hopper embraces the members of the sub-order Homoptera of Hemiptera. In these forms the wings are of one consistency throughout, and lie over the abdomen at an angle to one another much like the roof of a house (Fig. 27).

The **Cicadidæ** or Cicadas are large bugs distinguishable from other Homoptera by the possession of three ocelli. In size they range between one and three inches. On the whole they are forest pests, the adults sucking the bark of trees. The Cicadas are remarkable for the loud whistling sounds producible by the males and for the extreme length of the life-cycle.

*Cicada septendecem*, the Periodical Cicada or Seventeen

Year Locust of North America, remains in the nymphal phases for seventeen years in the ground, feeding upon the juices of roots and of soil humus. They moult four to six times, at intervals of two to four years.

The **Fulgoridæ** is the largest family of Homoptera and comprises both large, brightly coloured, day-flying, moth-like forms and small, dull coloured. grass-dwelling forms. They are feeders upon plant juices. *Perkinsiella saccharidida*, the Sugar Cane Leaf-Hopper, is a serious pest of sugar canes in Hawaii, although the damage to canes has been greatly reduced since the establishment of certain egg parasiting Hymenoptera from Australia, the original home of the leaf-hopper.

The **Jassidæ** or Leaf-Hoppers are small linear insects easily recognised by the spiny tibiæ. Their coloration usually harmonises with the surroundings. They occur commonly on grasses, low vegetation, on soil, more rarely on trees.

Some attack the cotton plant and cause leaf curling. *Empoasca facialis* is the Cotton Jassid of East and South Africa. *Empoasca flavescens* is the Greenfly of the tea plant, well known not only in India and Ceylon, but recorded also from Brazil, East Africa, Europe, North America. By sucking the apical shoots it checks the growth of the plants and lessens the yield, although said to improve the flavour. *Eutettix tenella* (Fig. 27) attacks beets in North America and acts as the carrier of "Curly Top," a virus disease of beets.

The **Membracidæ** or Tree-Hoppers are characterised by the presence of two ocelli below the eyes, by the insertion of the antennæ in front of and between the eyes, and by the backward prolongation of the prothorax into a conspicuous process.

They are small brown insects sometimes resembling stiff thorns. A few are recorded as pests in the United States, notably *Ceresa bubalus*, the Buffalo Tree Hopper, of orchards and shade trees; but on the whole the group is not of serious economic interest.

The **Cercopidæ** or Frog-Hoppers are distinguishable from Membracidæ by the simple prothorax and from the Jassidæ by the absence of tibial spines. To this family belong the "cuckoo spit" insects whose nymphs live within a mass of bubbles of liquid produced by themselves on the plant.

*Tomaspis saccharina* is a serious pest of sugar cane in Trinidad.

The measures for the control of plant bugs and plant-hoppers comprise :—

(1) The use of contact washes—kerosene emulsion, nicotine

sulphate, and so on—to which they are amenable; on field crops, however, such measures are often difficult or uneconomical.

(2) The destruction of weeds and organic rubbish in the vicinity of crops.

(3) Trap cropping.

(4) The encouragement of natural enemies.

**Plant Lice.**—The term is applied to the members of the families **Psyllidæ**, **Aleyrodidæ,** and **Aphididæ** of Homoptera; these, together with the **Coccidæ** or Scale Insects, are sometimes classed together as *Phytophthires*, a group characterised by:—

(1) A tendency towards a close parasitic interrelationship with the host plant.

(2) A tendency towards winglessness.

(3) The growing differentiation of an inactive nymphal condition, leading to the almost wholly inactive male "pupa" of Coccidæ.

**Aphididæ.**—The aphids are small rounded insects with two-jointed tarsi, and the abdomen usually provided with a pair of tubes through which a sweet liquid, *honey dew*, is emitted; this secretion is a favourite food of ants. Wingless forms are common, and wingless generations may alternate with winged forms in the life-cycle of the one species.

Under favourable conditions, aphids are usually parthenogenetic, producing eggs or living young without the intervention of a male; usually upon the onset of wintry or dry conditions, a generation of winged males and females is produced, and this generation may leave the summer host plants, usually a number of unrelated herbaceous plants, and fly to a definite winter host plant type, usually a single species or a few closely related species of woody stemmed plant. On the winter host plant fertilised eggs are laid; these "winter eggs" can withstand winter or dry season conditions, and at the onset of more favourable conditions can hatch into a generation of winged parthenogenetic females, the "stem mothers," which migrate to the summer host plants and commence the series of parthenogenetic wingless summer generations. The powers of increase of an aphid species are very great, owing to their rapid maturity and high egg production powers, but their natural enemies are proportionately numerous.

Aphids are universally feeders upon the sap of plants and many are serious cosmopolitan pests.

*Aphis gossypii*, the so-called Melon Aphis or Cotton Aphis, attacks a wide range of plants over the world. In the United States the winter eggs occur on purslane and strawberry.

*Brevicoryne brassicæ*, the Cabbage Aphis, is a cosmopolitan pest of cruciferous crops. The summer may be passed on cabbages and the winter on cabbage stumps.

*Phorodon humuli*, the Hop Aphis, is a serious pest in Europe and North America, spending the summer on hops and the winter on plum trees.

*Aphis avenæ*, the European Grain Aphis, attacks cereals in spring and summer, but winters on apple trees. It is established in Europe and North America (Fig. 27).

*Rhopalosiphum persicæ*, another aphis common to Europe and North America, infests garden crops such as spinach, potatoes, tomatoes, cabbages, lettuce, and so on in summer, but winters on peach trees or in greenhouses. On potatoes it is claimed that they convey the causative organism of a mosaic disease.

Some of the worst aphid pests are root-feeding forms, the transition from foliage feeding to root feeding having in many species been brought about possibly through the agency of ants. In many root-feeding species the migratory habit has become suppressed and the aphis spends the whole year upon the roots of a particular host type.

The **Woolly Aphis,** *Eriosoma lanigera*, attacks the roots and twigs of apple and pear trees in every apple-growing area of the world. It occurs on the twigs and branches as little white wool-like patches, each composed of a number of aphids which bear long threads of wax. Swellings and enlargements of the branches are caused. Root-feeding forms lack the waxy threads.

In North America there is a cross migration from apple to the elm (*Ulmus americana*) in autumn, and a return migration to apple in early summer, although some aphids remain on apple all the year round. Outside America this cross migration seems not to occur except in districts where the American elm has been introduced.

Originally a native of North America, the Woolly Aphis although seriously destructive in the warmer regions of that area, is checked there considerably by the Chalcid parasite *Aphelinus mali*, and attempts are being made to establish this parasite in other apple-growing regions of the world.

Some varieties of apple, notably Northern Spy and Majetin, are considerably resistant to woolly aphis attack, and in some apple-growing areas it is customary to graft susceptible varieties of apple on to root stocks of such resistant varieties.

The **Vine Aphis,** *Phylloxera vastatrix*, is another aphis

indigenous to North America, but established in Europe and other areas. This aphis has a life-cycle confined to the grape vine, but including root feeders and leaf feeders. The leaf feeders (gall-makers) are comparatively harmless; the root-feeding aphids produce (*a*) small galls (nodosities) near the tips of the young rootlets, (*b*) large swellings (tuberosities) upon older rootlets and roots. The first class of root gall occurs on all vines, resistant or susceptible, if *Phylloxera* be present, and is not particularly injurious. The difference between susceptibility and resistance to *Phylloxera* is, in fact, a question of the numbers, size, and penetration of the tuberosities. The original home of this species of *Phylloxera* is generally regarded as being North America, although a certain amount of evidence has been brought forward to indicate the possibility of the region around the Black Sea of Europe as being the place of origin.

Certainly North America is the home of the majority of the Phylloxeran species, and nearly all species producing leaf galls occur there exclusively. The interesting suggestion has been made that the original habitat of *Phylloxera vastatrix* was the uniformly moist rain forests of tropical and sub-tropical America where, infesting the genus of vine *Euvitis*, the insect was able to live not only in leaf galls but on all parts of the plant above and below ground. The present-day type of root form may have become fixed in adaptation to life in drier regions.

The vine louse was discovered on an American vine by Fitch in 1864, and later on it was found on wild vines in the Mississippi basin. It was not known in Europe before the 'sixties, and was almost certainly introduced upon vines imported from America. The wild vines of America show all gradations of resistance to *Phylloxera vastatrix*, from almost complete immunity to complete susceptibility. Probably the insect has gradually adapted itself to certain varieties. The more resistant species belong to the genus *Euvitis*, and are, in order of resistance, expressing the maximum or absolute immunity as 20, as follows: *E. rupestris*, 18-19; *E. riparia* and *E. cordifolia*, 18; *E. berlandieri*, 17; *E. cinerea*, 16; *E. æstivalis*, *E. linsecomii*, and *E. candicans*, 14-15.

On the other hand, the species of vine to which the three thousand or so European varieties belong, viz., *Vitis vinifera* and *Vitis silvestris*, have proved highly susceptible to the introduced *Phylloxera*, so much so that viticulture in Southern France and Italy was severely checked by its appearance.

The hope that it would be possible to obtain hybrids between resistant American vines and *Vitis vinifera*, equal in size,

quality, and yield to the latter parent, has proved futile, since resistance to *Phylloxera* and quality of fruit seem to a great extent to be antagonistic qualities; the hybrids yielding the best wine are usually insufficiently resistant, and *vice versa*. The only practicable method, in fact, of dealing with *Phylloxera* in an infested district lies in the use of graft hybrids, the grafting of *vinifera* varieties upon *Euvitis* root-stocks. In the main, root-stocks of the species *rupestris* and *riparia* are used, or hybrids between *riparia* and *berlandieri*, or of crosses between such hybrids and certain varieties of *vinifera*.

*Anuraphis maidiradicis*, the Corn Root Aphis, attacks the roots of maize and other plants in spring and summer, and of grasses in winter. It is a North American species. It is cultivated and carried from winter hosts to summer hosts by a small ant, *Lasius niger*, known as the cornfield ant, and the aphis depends solely upon the ant for its existence. It is, in fact, a domesticated animal.

The control of aphids comprises generally the use of contact poisons, usually emulsions of soap and water containing kerosene, nicotine, and so on.

**Psyllidæ.**—The jumping lice or Psyllidæ are minute insects similar in size and appearance to aphids, but lacking the siphons. The older nymphs are flat, inactive, scale-like forms, often living within plant galls; the young nymphs and the winged adults, however, are capable of active, leaping movements.

*Psylla pyricola* of Europe and North America infests pear trees.

*Psylla mali* is the Apple Sucker of Europe.

**Aleyrodidæ.**—The Whiteflies are minute, moth-like insects with white, floury wings. They are distinguished sometimes with difficulty from Scale Insects, but the adult males and females, however, have two pairs of wings, whereas the Scale Insects are winged only in the adult male stage, and this has only one pair of wings.

*Asterochiton vaporariorum* is the Greenhouse Whitefly of Europe and North America. *Dialeurodes citri* is a citrus pest of North America.

**Thrips** is a term applied to the members of the order Thysanoptera, a family of minute insects with two pairs of fringed wings which includes several notorious pests of plants.

*Thrips tabaci*, the Onion Thrips, is cosmopolitan and attacks a wide range of food plants besides the onion. *Heliothrips hæmorrhoidalis* is the principal greenhouse thrips of Europe and North America. *Heliothrips indicus* attacks indigo in

India and cotton in the Anglo-Egyptian Sudan, being there the major pest of cotton. *Heliothrips rubrocinctus* is the Cacao Thrips of most cacao-growing regions. *Frankliniella tritici* is a serious cereal pest of wheat-growing regions.

**Flea Beetles.**—The term flea beetle refers to a member of the beetle family *Chrysomelidæ*, a large and varied collection of small, smooth, often hemispherical beetles which feed on plant foliage. The larval stages may be foliage feeders also, or may be foliage miners or may be root feeders.

The *Chrysomelinæ* or foliage-eating forms include particularly *Leptinotarsa decemlineata*, the Colorado Potato Beetle. This black and yellow striped beetle is a pest of potatoes in the United States, having spread from the buffalo bur, a wild species of *Solanum* in Nebraska, where it was observed in 1859, from potato field to potato field, right across the States to the Atlantic seaboard. It is also established in France.

Among root-feeding forms may be mentioned *Diabrotica vittata* of North America, the black and yellow adults of which feed openly on the foliage and flowers of cucurbitaceous plants, the larval stages being root burrowers.

Similar root-feeding habits are shown by the larvæ of *Phyllotreta*, a small leaping beetle which attacks cruciferous crops, particularly mustard and turnip, in Europe and North America.

*Nisotra* is a flea beetle which seriously attacks cotton plants in Northern Africa.

**Weevils.**—The *Curculionidæ*, popularly known as weevils or billbugs, form the largest natural family in the animal kingdom.

They are characterised among beetles by the projecting snout and the clubbed, elbowed antennæ.

The larvæ are small, limbless white grubs, usually somewhat curved, and they show considerable variety of habitat; all agree, however, in being herbivorous, and the great majority are subterranean or internal feeders.

Among the varieties of larval habitat may be mentioned :—

(*a*) *General plant eaters*, such as the species of *Apion*.

(*b*) *Foliage eaters*, such as *Hypera*, *Cionus*, whose larvæ adhere to the foliage by means of a gummy secretion, and *Attelabus*, *Apoderus*, and *Rhynchites*, whose larvæ live in a portion of the leaf rolled into a tube by the parent.

(*c*) *Root feeders*, such as *Otiorhynchus*, *Sphenophorus*, *Sitones*, *Tanymecus*, *Myllocerus*. *Otiorhynchus* is a notorious genus of wingless weevils whose adult stages feed on foliage and whose larval stages feed on the roots of fruit trees and other

plants. *Sphenophorus* comprises the Corn Billbugs of the U.S.A. *Sitones* does great damage to young peas and beans.

(*d*) *Stem dwellers*, such as *Ceutorhynchus*, *Cryptorhynchus*, *Ryncophorus*, *Hylastes*, *Hylobius*, *Pissodes*, *Lixus*, *Apion*, *Cylas*, *Phylaitis*. *Ceutorhynchus*, the Turnip Gall Weevil, with species in Europe and North America, attacks cruciferous crops, the larvæ living within large galls on the roots. *Hylobius abietis*, the Pine Weevil, is one of the worst forest pests in Europe to coniferous trees. The adults gnaw the tender bark in such a manner as to present the appearance of rabbit damage ; the eggs are laid, however, on trees which have been felled two or three years before, and the larvæ make winding galleries below the bark of the roots. *Pissodes* is another dangerous genus with similar habits.

*Oryctes rhinoceros*, the Rhinoceros Beetle, is an enormous weevil which feeds on the soft tissues and unopened leaves of the coconut palm in India and the East Indies ; the larvæ live around plant roots and in decaying vegetable matter. Coconut, toddy, and date palms are attacked also in India, the Straits Settlements, and Ceylon by the Red Palm Weevil, *Rhyncophorus ferrugineus*, whose larvæ tunnel in the soft tissues of the palm.

(*e*) *Bud borers*, such as *Anthonomus*, *Conotrachelus*, *Dorytoma*. **Anthonomus grandis,** the **Mexican Cotton Boll Weevil,** may be said to be, as concerns the financial aspect of its ravages, the world's major cotton pest, although restricted to the cotton-growing belt of North America.

It appeared in 1892 at Brownsville in Texas, and has since spread over the entire cotton belt, although not doing serious damage every year over the whole of the belt (Fig. 28).

It is a small, dark coloured weevil which feeds and lays eggs in the young square, that is to say, the bud prior to blooming, and in the young fruit or boll. The larva hatches in a few days and begins feeding within the square (Fig. 29). After about eight or ten days, pupation takes place within the same square, which by this time has usually fallen to the ground, and within a few days the weevil emerges. The entire life-cycle requires about twenty-two to twenty-five days, and the number of generations per year varies from one to three.

The weevil is a strong flier, even against prevailing winds, and migration flights from a field seem to occur after the degree of infestation of the plant has become as high as 60 per cent. of bolls infested. The flights are dependent on the occurrence of moderate winds, and the extent of the flights depends again

upon whether the new area contains small scattered cotton fields or whether it is almost exclusively devoted to cotton.

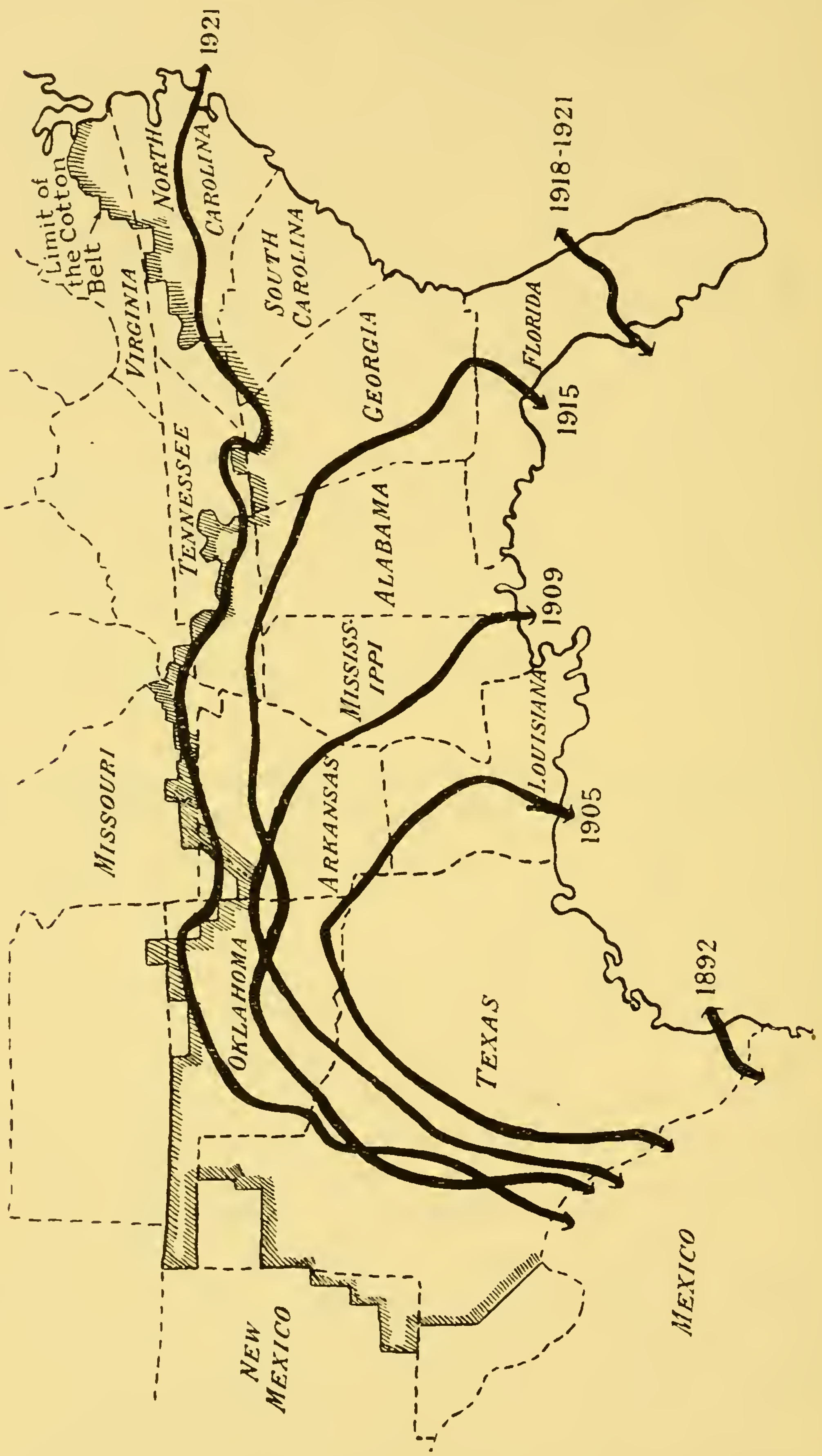



FIG. 28.—The Spread of the Cotton Boll Weevil.

In the latter event the spread of the insect will be slower and more limited than if the fields are scattered.

Common practices in the control of the boll weevil are :—

(1) Dusting with calcium arsenate, a very efficient control,

especially if the dusting be carried out by aeroplanes, but having the drawback that the area that can be covered is small.

(2) Early planting.

(3) Use of quickly maturing varieties.

(4) Spacing of plants closer together in the drill and farther apart as regards distance between rows.

(5) Liberal fertilisation.

(6) Frequent and rapid cultivation.

(7) Collection and destruction of infested squares. Sometimes as high as 30-40 per cent. control has been obtained in this way, but many parasites may be destroyed also unless the squares are put in screened cages which allow the smaller sized parasites to escape but retain the emerging weevils.

(8) Chopping and ploughing under of stalks in the fall.

(9) Cleaning up hibernation quarters.

There are fifteen parasites which are known to attack the weevil in more or less economic numbers. Of these, *Bracon mellitor* is the most important, since it occurs over the entire belt.

Some work has been done also in breeding a variety of cotton whose bolls will be too hard for the weevil to puncture, but results so far have not been conclusive.

**Anthonomus pomorum** of Europe and **Anthonomus quadrigibbus** of North America are close relatives of the Boll Weevil, similar in appearance, similar in habits.

The female weevil drills a hole into an expanding blossom bud of the apple and inserts eggs. The resulting larvæ remain feeding within the buds which, consequently, do not open but fall to the ground. Pupation takes place within the dead bud, and the beetle eats its way out when mature. The adults feed on apple foliage.

Control methods comprise the destruction of winter shelter by keeping tree trunks free from loose and rough bark; the shaking of infested trees to bring down injured blossoms which can then be burned; the jarring of adult beetles from the trees on to cloths and their subsequent destruction.

*Anthonomus signatus* attacks strawberries in similar fashion in the United States.

(*f*) *Seed eaters*, such as *Balaninus*, *Sitophilus*, *Alcides*, *Cryptorhynchus*, *Craponius*. **Sitophilus granarius** and **Sitophilus oryzæ** are small, reddish-brown beetles, cosmopolitan in distribution, which attack stored cereals. The eggs are laid in a tiny cavity gnawed out of the grain. The larval stage is passed within the grain, and pupation occurs within it, but the adults live on the outside.

They will breed all the year round in stored grain in warm buildings. They are susceptible, however, to a high carbon dioxide content, to a low degree of dryness, and to low temperatures. *Oryzæ* become dormant at approximately 7·2° C. (45° F.) and *granarius* at 1·6° C. (35° F.), and in this condition they will perish in seventeen and thirty-eight days respectively.

*Craponius inæqualis*, the Grape Curculio, is one of the worst pests of the grape in North America, east of the Rocky Mountains.

**Noctuid Caterpillars** belong to the family *Noctuidæ* of moths, a family of night-flying, somewhat robust and densely hairy moths. According to their economic activities, these caterpillars may be grouped into :—

(*a*) **Cutworms** or surface caterpillars, which have been already discussed.

(*b*) **Army worms,** which are caterpillars of the sub-family *Hadeninæ*, and are forms which occasionally become excessively abundant and migrate in hordes from one area to another. The best known army worm is the cosmopolitan **Cirphis unipuncta,** originally a native of North America, but occurring now in South-east Asia, Europe, Australia, New Zealand, and South America ; it tends to appear in enormous numbers, stripping the fields of cereals of their leaves and ears, and then will migrate in masses to fresh fields. The winter is passed by the caterpillars in hiding among bunches of grasses ; they pupate in early summer, and the emerging moths produce the " July brood " of caterpillars ; these again give rise to moths which emerge in August and produce the " September brood " of some caterpillars. In some latitudes three or even four broods a year may occur.

(*c*) **Bollworms,** a name applied to caterpillars which bore into the seed receptacles of the fruits of Malvaceous plants, the cotton plant in particular, and feed on the developing seeds.

The more important Noctuid bollworms are :—

The Spiny or Egyptian Bollworm, *Earias insulana*, of India, Egypt, and East Africa ; the Sudan Bollworm, *Diparopsis castanea*, of Africa ; the South American Bollworm, *Sacadodes pyralis* ; and the Cotton Bollworm, *Chloridea obsoleta*, which attacks cotton only in North America, and is primarily a pest of corn, cotton being only attacked by the third brood at a time when the maize heads are too hard to penetrate.

(*d*) **Leaf eaters,** a term which covers a large number of Noctuid pests. In a few leaf-eating genera, notably *Cosmophila*, *Eublemma*, the first two pairs of sucker feet are lacking and the

caterpillar is termed a "semi-looper." *Prodenia littoralis* is a cosmopolitan pest of many crops, particularly of tobacco, flax, and cotton. *Caradrina*, *Plusia*, *Hadena*, *Mamestra* are all important genera to the economic entomologist. *Mamestra brassicæ* is the Cabbage Moth of Great Britain.

For a discussion of the majority of injurious species, reference may be made to Sorauer.

**Loopers** or **Cankerworms** are caterpillars of the family Geometridæ, a very large family of slender moths with relatively large wings. The caterpillars are long and slender, and possess abdominal legs or sucker feet only on segments six and ten; in walking, therefore, owing to this gap between the two pairs of sucker feet, the caterpillar's body is alternately arched dorsally to form a loop, and then straightened out again (Fig. 27).

The great majority of Geometrid caterpillars are extremely similar in colour to twigs or leaf ribs, and so resemble very closely their normal surroundings. Although not, as a family, very important economically, they include some important pests.

In North America the cankerworms, *Alsophila pometaria* and *Paleacrita verbata*, and the Apple Span Worm, *Ennomos sunsignaria*, strip the foliage from apple trees. In Great Britain species of *Cheimatobia*, *Hybernia*, and *Anisopteryx* do similar damage; these moths have wingless females, and one common preventive method used against them is that of placing bands of sticky grease around the tree trunks in autumn in order to trap the wingless females as they crawl up the trunk in order to reach the twigs on which they prefer to oviposit.

**Tussock Caterpillars** belong to the families Lasiocampidæ and Lymantriidæ of moths. They are hairy caterpillars with thick compact tufts of poisonous spines or hairs along the dorsal surface (Fig. 27).

The Lasiocampidæ include in particular the genus *Malacosoma*, the Lackey Moth. *Malacosoma neustria* is a defoliating shade tree and fruit tree pest in Europe, Western Asia, Siberia, China, and Japan. The eggs are laid in a band around a twig, and the young caterpillars feed under a common web and are hence sometimes termed "tent caterpillars."

The allied species, *Malacosoma americana*, is the Apple Tree Tent Caterpillar of North America.

Control measures comprise the collection and burning of egg rings during autumn, winter, and spring; the destruction of wild cherries and seedling apple trees; the spraying of infested trees with arsenate of lead just as the buds are opening.

The true tussock caterpillars include the **Gipsy Moth**

*Porthetria dispar*, and the **Brown Tail Moth,** *Nygmia phæorrhea*, feeders upon a wide variety of forest, orchard, and shade trees. The eggs are laid in spongy masses of 400-500 in crevices during late summer, remain unhatched during the autumn and winter, and hatch in the following spring.

Although indigenous to Western and Central Europe, these two moths were introduced accidentally into Massachusetts, the Gipsy Moth by a Harvard professor of Physics in 1869, and the Brown Tail on plants from Holland about 1893. Both pests have become firmly established in New England generally, and have spread with alarming rapidity in spite of the enormous expenditure of money and effort that has been put forward by the States concerned.

Control measures comprise :—

(*a*) The creation of a barrier zone on the fringe of the infested areas in western New England and eastern New York, within which infestation is reduced as far as possible by high pressure spraying of trees with arsenate of lead and by destruction of the egg clusters with creosote ; all plants coming westward through this zone are rigorously inspected.

(*b*) The importation of parasitic insects from Europe. Intensive collecting by United States agents in Europe has, during the last twenty years, resulted in large shipments of parasites to the Melrose Highlands Laboratory in Massachusetts, from which centre the parasites are distributed for liberation in the infested areas.

## CHAPTER XV

### INSECT PESTS: The Categories—*Continued*

In the previous chapter, discussion has been confined to such types of insect pest as are not, in general, closely restricted in choice of food plant nor in powers of migration. Some consideration may now be given to types which show a tendency towards close limitation in range of food plants and, owing to plant attachment or plant mining or other similar habits, show a tendency to be restricted in area of distribution, unless carried from one area to another by human agency.

**Scale Insects.**—The Hemipterous family **Coccidæ** or scale insects affords some of the most striking examples of the readiness with which an insect type, feeding in its indigenous habitat possibly upon wild plants, may be transferred accidentally by man into a new area and rapidly adapt itself to cultivated food plants.

In agricultural areas the scale insects of economic importance are almost always orchard pests, and occur upon the outer surface of the fruit-tree twigs or foliage or fruit as tiny shell-like structures, comparable in shape often to oyster or mussel shells. Beneath each scale is the wingless, degenerate female, her suctorial proboscis imbedded in the plant tissues, completely incapable of moving from the particular site she selected when in the active larval state. The eggs are laid beneath the scale or beneath the parent body. The newly hatched young emerge from beneath the parent scales in early summer, swarm over the trees, and in a few hours settle down, insert their beaks, and begin to manufacture the circular grayish scale.

Some species are parthenogenetic, males being unknown. In other species males are more abundant than females. The male is winged, active, and incapable of feeding.

The so-called "scale," or covering, varies in its nature; it may be a true scale formed of felted threads and cast skins, or it may be the thickened dorsal cuticle; it may be a covering of wax plates or of resinous material; or, again, it may be merely a powdering of waxy dust.

Of the wide range of injurious scale insects, the species

probably of greatest importance to the world's fruit-growing industries is the **San José Scale,** *Aspidiotus perniciosus,* so

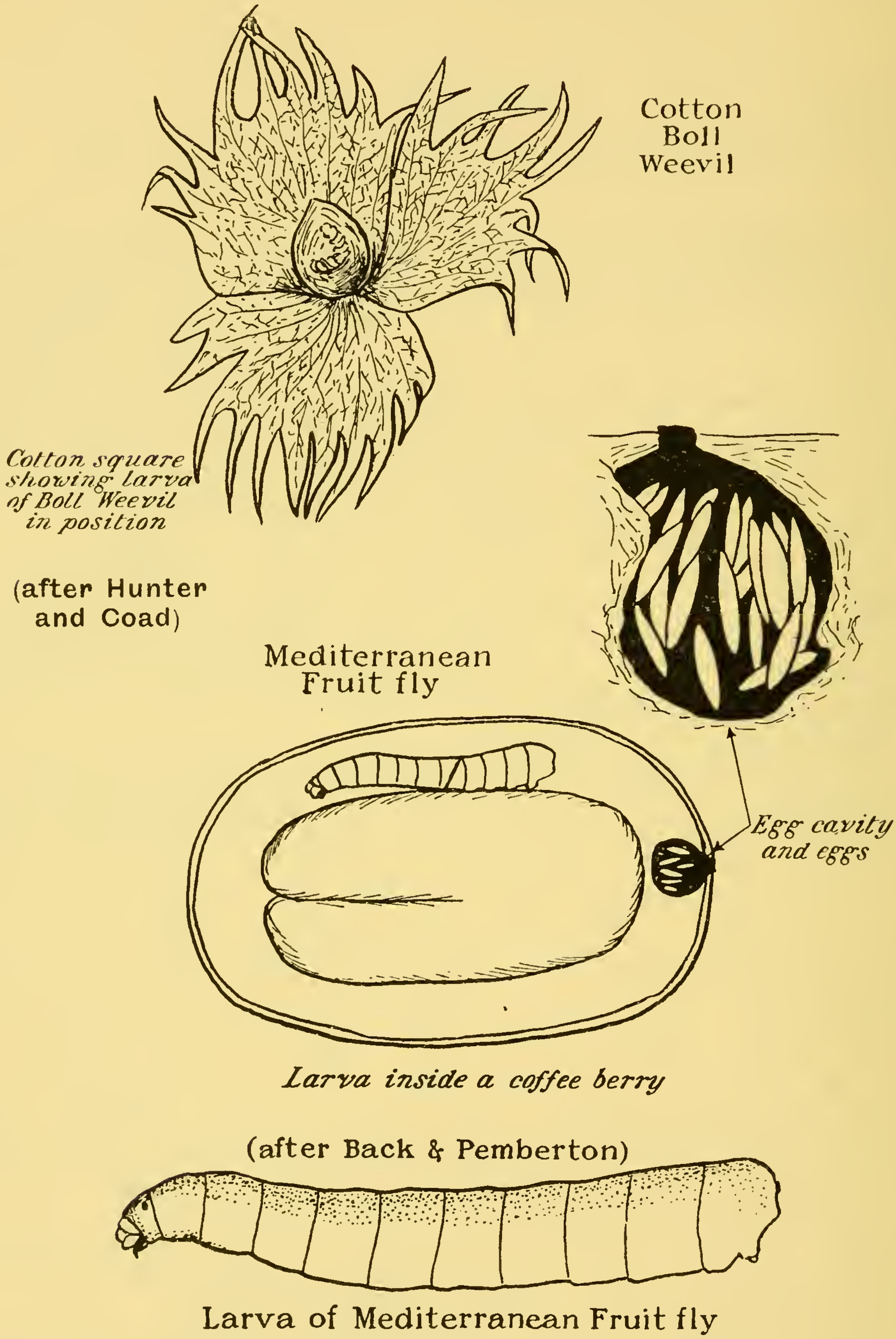



Fig. 29.—Types of Insect Pest. (Not to scale.)

called because it appeared as an economic pest first in the orchards of San José in California, probably as an immigrant from China on the flowering peach. Since then it has spread

into all the fruit-growing districts of North America. It occurs in the form of a dense incrustation of perfectly circular yellowish scales, one-sixteenth of an inch in diameter each, with a dark central spot, covering usually the surface of the twigs but occurring also on the foliage and fruit (Fig. 30). It is a wide-spread feeder. Peach and pear are particularly susceptible and are quickly killed, but the Chinese pear and the Kieffer and Leconte varieties of pear, hybrids between *Pyrus sinensis* and *Pyrus communis*, show considerable resistance.

The control measures adopted in American orchards against the scale comprise :—

(1) The destruction of the adult insects by spraying with contact poisons, particularly with lime-sulphur (solutions of alkaline sulphides and polysulphides), emulsions of mineral lubricating oils, and so on.

(2) The encouragement of enemes and parasites. Much was hoped from the ladybird beetle, *Chilocoris similis*, which was imported from China to California in large numbers, but unfortunately it is an easy prey for certain native parasites, and where spraying is carried on, cannot procure enough food to maintain its existence in numbers.

*Aspidiotus* belongs to the sub-family **Diaspinæ** or Armoured Scales ; in these the scale consists of three distinct products, namely, the moulted skins of the first and second nymphal stages of the female, or the first of the male ; a mass of silken threads poured out through openings in the dorsal surface ; and an excretion from the Malpighian tubules emitted through the anus.

Belonging also to this sub-family are many other notorious pests, notably :—

The Oyster Shell Scale, *Lepidosaphes ulmi*, a pest of the elm, apple, pear, plum, willow, dogwood, etc., in North America, Brazil, Japan, Australia, Europe.

The Purple Scale, *Lepidosaphes pinnæformis*, on orange, lemon, fig, grape-fruit, oak, croton, *Banksia*, *Taxus*, etc., in Europe, America, Asia, Africa, and Australia.

The European Fruit Tree Scale, *Aspidiotus ostræformis*, on shade and fruit trees in Europe and America.

The Red Scale, *Aonidiella aurantii*, and Florida Red Scale, *Chrysomphalus*, cosmopolitan pests of a wide variety of fruits.

The Peach Scale, *Aulacaspis pentagona*, a world-wide pest of orchards.

To the sub-family **Monophlebinæ**, characterised by a woolly or powdery covering of wax which surrounds the insect or under-

lies it, belongs **Icerya purchasi,** the Fluted or Cottony Cushion Scale. The popular name refers to a large cushion of wax, with a fluted surface, which intervenes between the body of the female and the surface of the plant. This waxen cushion is the ovisac and encloses a mass of eggs.

The Fluted Scale was accidentally introduced from Australia into California, and threatened at one time to destroy the citrus-growing industry of that state. However, an agent of the United States Department of Agriculture, Professor Koebele, discovered in Australia a ladybird beetle, *Vedalia cardinalis*, which in that area keeps the Fluted Scale down to proportions harmless to the horticulturist.

These beetles were imported into California in large numbers and established there. Within five years the number of Fluted Scales was so greatly reduced that the menace to the citrus industry was removed. Similar beneficial results followed upon the introduction of this beetle into other areas where the Fluted Scale was a pest, notably into New England, South Africa, Portugal, Italy, Southern France, Egypt, Formosa, Hawaii, Syria.

*Vedalia cardinalis* seems to afford a perfect remedy against the Fluted Scale. There are, however, many reasons in its favour which do not hold in the case of other beneficial insects. In the first place, the host insect is fixed to the plant and cannot escape the mobile beetle. Secondly, *Vedalia* is a rapid breeder, producing two generations to the Coccid one, and both larval and adult stages are egg feeders. Thirdly, it is able to adapt itself to new environmental conditions. Finally, it seems to have no enemies, a remarkable feature since, as a rule, these beetles are liable to attack by many species of parasites.

Somewhat variable results, in fact, have followed attempts to introduce other species of ladybird beetles. Thus Koebele introduced also from Australia the ladybird beetle, *Cryptolœmus montrouzieri*, into California to fight various species of scale insects, and great success was claimed; but other areas have been unable to obtain results of appreciable value. Many ladybird beetles, belonging to the genera *Rhizobius*, *Lipernes*, *Serangium*, *Frithionyx*, *Scymnus*, *Chilocoris*, and most promising of all, *Oreus chalibœnus*, have been introduced into California to fight San José Scale but without marked success.

The sub-family **Eriococcinæ,** or Mealy Bugs, comprise scale insects whose bodies, both dorsal and ventral aspects, are enclosed in a fine granular wax which makes them look as if

they had been rolled in coarse flour ; the family includes some of the most injurious cosmopolitan scale insects, notably the Citrus Mealy Bug, *Pseudococcus citri.*

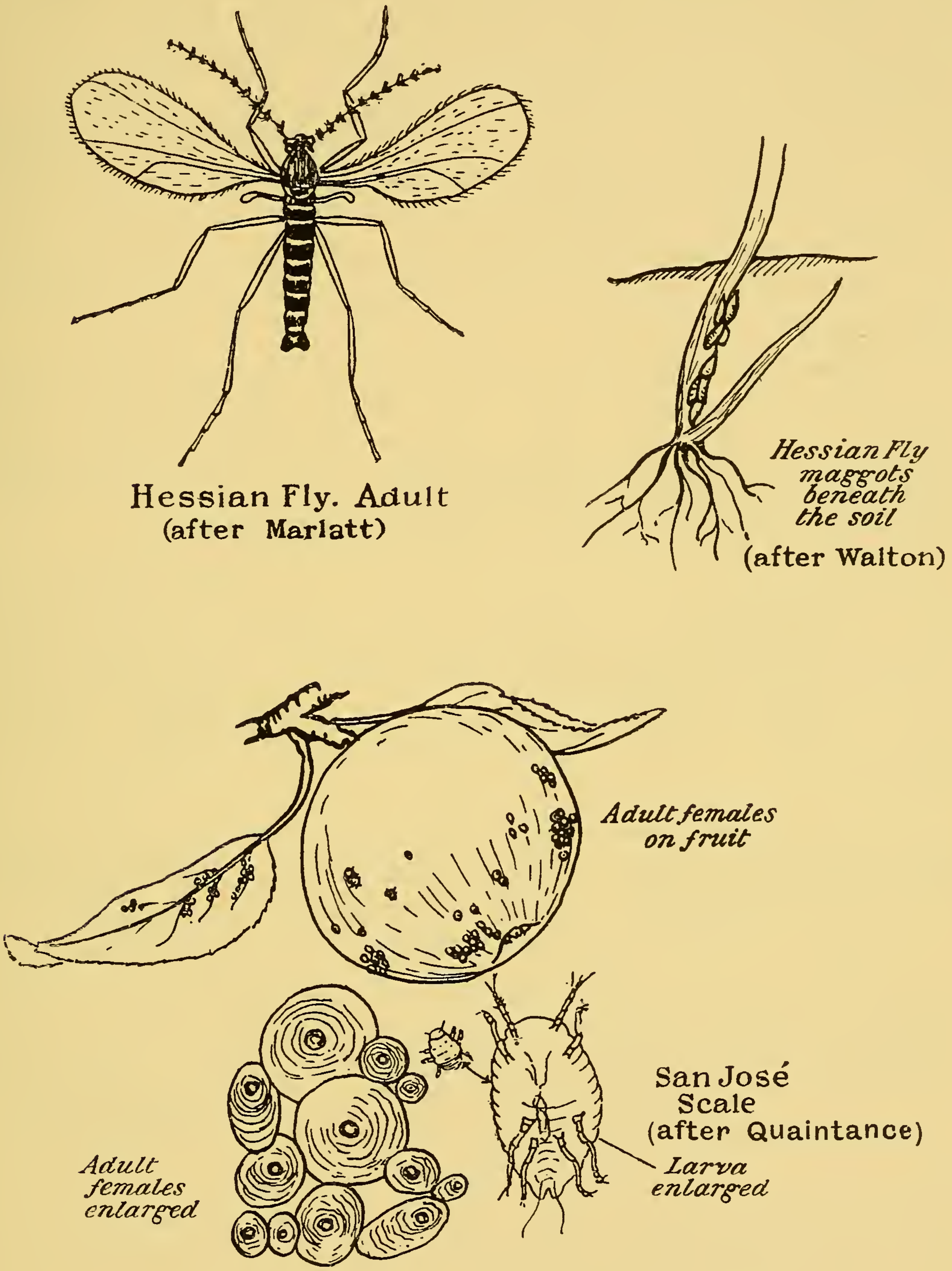



Fig. 30.—Types of Insect Pest. (Not to scale.)

The sub-family **Lecaniinæ,** or Tortoise Scales, comprises scale insects varying in appearance from hemispherical forms, like half peas, with no proper scaly covering, to forms enclosed in a large mass of wax.

*Saissetia oleœ*, the **Black Scale,** is one of the worst citrus pests

in the world ; it attacks a wide variety of fruit trees, however, in addition to citrus. It is a hemispherical scale, dark brown in colour, with an H-like dorsal mark. In California, attempts are being made to control this insect by the establishment of a South African Chalcid parasite, *Scutellista cyanea*, and an Australian parasite, *Aphycus lounsburyi*. *Saissetia oleæ* may be destroyed to the extent of 70-80 per cent. by these egg-devouring parasites, yet even this large percentage mortality does not suffice to check excessive multiplication of the scale insect when conditions afforded by the host plant are favourable.

**Mining Insects.**—The habit of mining in the foliage, stem, root, or fruit of plants is one not confined to any particular insect order.

Among Lepidoptera, where of course the habit occurs only among the caterpillars, the following families are characteristically miners : the Clear Wings (**Sesiidæ**), Goat Moths (**Cossidæ**), Seed Moths (**Gelechiadæ**), Clothes Moths (**Tineidæ**), Fruit Moths (**Tortricidæ**), Moth Borers (**Pyralidæ**).

Among Coleoptera the habit occurs in the Powder Post Beetles (**Lyctidæ**), Furniture Beetles (**Anobiidæ**), Flat-headed Borers (**Buprestidæ**), Round-headed Borers (**Cerambycidæ**), Shot-hole Borers (**Scolytidæ**), Pulse Weevils (**Bruchidæ**), Bud Weevils (**Curculionidæ**), Drug Store Beetles (**Ptinidæ**). Among mining beetles, usually both larval and adult forms have the habit.

Among the Diptera, the chief mining families are the Gall Midges (**Cecidomyiidæ**), Root Maggot Flies (**Anthomyiidæ**), Fruit Flies (**Trypetidæ**), and Grass Stem Flies (**Oscinidæ**).

Among the Hymenoptera, where as in Lepidoptera and Diptera the habit is confined to the larval stages, the following families are characteristically mining in habit : Stem Saw-Flies (**Cephidæ**), Wood Wasps (**Siricidæ**), Gall Wasps (**Cynipidæ**), Stem Chalcids (**Chalcidoidæ**), and Seed Chalcids (**Chalcidoidæ**).

The Clear Wing Moths, **Sesiidæ,** constitute a family of small moths, most of which differ from the usual type of moth in possessing transparent wings. They bear a superficial resemblance to Hymenoptera, especially as they are rapid fliers and appear during hot sunshine.

A Sesiid moth usually lays her eggs on the side of the main stem of a living plant ; the caterpillar bores laterally to the centre of the stem, then tunnels downwards for several inches in the sap wood ; in some cases the subterranean portion of the stem is attacked. When full fed, the caterpillar tunnels laterally until just below the bark and remains there all winter ;

in spring it completes the tunnel to the surface, pupates in the tunnel or beneath a loose piece of bark, and the moth emerges in early summer.

*Sesia*, *Trochilius*, *Melittia*, *Membecia*, *Ægeria*, *Memythrus*, *Sanninoides* are Sesiid genera whose caterpillars attack fruit trees in Europe and North America. *Sesia tipuliformis* is the Currant Borer of these areas. *Ægeria exitiosa* is the Peach Tree Borer of North America.

The Goat Moths, **Cossidæ,** are medium to large-sized moths, usually greyish-brown in colour, with long narrow wings and long abdomen. The larvæ mine usually in hardwood trees, eating large tunnels through the wood, and in many cases give off an unpleasant goat-like smell. Pupation occurs in the tunnel, and the moth emerges by a hole made by the caterpillar prior to pupation.

The **Leopard Moth,** *Zeuzera pyrina*, is a white moth with steely-blue round spots on the wings, whose larvæ bore in the trunks of hardwood forest trees. It is a common pest in the forests of Europe and Northern Africa and has become established in North America.

An allied species, *Zeuzera coffeæ*, is a pest of coffee, tea, cinchona bushes, sandalwood trees, etc., in India, Ceylon, Java, and East Africa.

The Seed Moths, **Gelechiadæ,** are small moths somewhat like clothes moths in appearance, with the hind wings characteristically pointed at the apex. The term " seed moth " is a convenient one in that some of the more important species have the larval habit of tunnelling in seeds, but actually the larval habits vary considerably between species.

The **Pink Bollworm,** *Pectinophora gossypiella*, is the major pest of cotton in India and Egypt, and is established also in China and Japan, in the Philippines, Hawaii, America, West Indies, and the Sudan.

In India it is controlled somewhat by the Braconid parasite *Rhogas*, but in Egypt great annual damage is done to the cotton crop, despite rigorous seed sterilisation measures enforced in every ginnery. The eggs are laid on all parts of the plant, singly, or, when at the base of the squares (flower buds), in masses. The larvæ enter the squares and feed on the future floral organs. Later they enter developing bolls (fruits), eat the seeds and lint and pupate within the emptied seed. It is this pupation habit which renders the insect one that is easily carried from country to country in consignments of seed.

No adequate control measures exist beyond an efficient

system of sterilisation of all seed by steam heat, sun heat, or chemicals in the ginneries.

The **Angoumois Grain Moth,** *Sitotroga cerealella*, is similar in habit to the Pink Bollworm, but lives as a caterpillar within the grains of cereals. It is a European pest which has become firmly established in other areas of the world.

The **Potato Tuber Moth,** *Phthorimœa operculella*, is a cosmopolitan Gelechiid whose caterpillar mines in the foliage and in the tubers of the potato plant. It attacks tubers in the field or in storage, and may be extremely destructive to stored seed potatoes.

The Clothes Moths, **Tineidæ**, are minute, dull coloured moths, whose wings are narrow, fringed with scales, and fold flat over the body when at rest. The caterpillars are usually leaf miners or case bearers. The Case-making Clothes Moth, *Tinea pellionella*, attacks particularly furs, woollen clothing, carpets, and feathers ; the caterpillar lives within a cylindrical case of silk and fragments of the material upon which it is feeding.

The Tapestry Moth, *Trichophaga tapetzella*, attacks usually coarser materials than does *pellionella* ; the caterpillar may tunnel through the pile of a carpet, lining its galleries with silk, or it may feed on the surface of its medium but within a silken gallery.

The Webbing Clothes Moth, *Tineola biselliella*, makes neither case nor gallery ; the caterpillar feeds on woollen stuffs, furs, even on cobwebs.

Other Tineid caterpillars may be found feeding on dried refuse, dead wood, dried fruit, fungi, bird nest débris, etc.

The Fruit Moths or **Tortricidæ** are a large family of small dull coloured moths with densely scaled wings ; the forewings are long and have often a characteristic hump on the anterior margins ; when at rest the wings wrap round the body. Usually the moths are nocturnal fliers. The caterpillars are usually greyish-white in colour, with very few hairs. The majority roll the leaf they feed upon into an enclosing tube, or they weave several leaves together to cover themselves, but some larval forms burrow in fruit, in flower heads, or in plant stems.

Of such tunnelling forms, the most important from an economic standpoint is the **Codling Moth,** *Cydia pomonella*, a moth indigenous to Europe, but now one of the most destructive pests in every apple-growing area of the world.

The moth is small, about three-quarters of an inch across

the wings, greyish-brown in colour, and a night flier, being on the wing usually within a fortnight from the fall of the petals of the apple blossom. It attacks all varieties of apple, and within three weeks from the fall of the petals the adult female will lay sixty to seventy-five eggs on the leaves, twigs, or commencing fruit. The caterpillar is whitish, with black body tubercles and a black head. For a short time it feeds on the leaf on which it has hatched, but eventually it finds its way to a young fruit and enters it, in the majority of cases, at the calyx end. It gradually eats its way to the core, and in three or four weeks is full fed and ready to emerge from the apple. From the apple it drops to the ground and then commences to ascend the nearest apple tree trunk in order to find a suitable loose piece of bark beneath which to spin its cocoon.

In the case of the second brood, the larva enters the apple from the side. In Great Britain, New England, Canada, only one brood occurs during the summer, but farther south there may be as many as three. The winter is spent usually within the cocoon as a full-fed larva, pupation occurring in the spring and coinciding usually with the blossoming time of the apple trees. Some, however, are known to winter as pupæ.

Control measures against the Codling Moth comprise spraying the trees with arsenicals just after the fall of the blossoms, and banding of the trees with bands of coarse canvas to provide a trap shelter for hibernating caterpillars; the bands are removed in winter and destroyed.

The Lesser Apple Worm, *Laspeyresia prunivora*, of North America, is sometimes confused with the Codling Moth, but the larval galleries are nearer to the surface of the fruit than those of the latter form.

*Laspeyresia molesta* is the notorious Oriental Peach Moth of North America.

*Laspeyresia nigricana*, the Pea Moth, injures pea-pods in Europe and North America. *Laspeyresia pseudonectis* is the Sann Hemp Borer of India. *Polychrosis botrana* of Europe and *P. viteana* of North America are vine moths. The first brood of caterpillars feeds on the blossoms and young fruit, webbing the clusters together; the second brood tunnels within the fruit.

*Clysia ambiguella* bores into the flower buds of the grape vine in Europe.

*Eucelis funebrana* is the Plum Moth of Europe.

The caterpillars of the Apple Bud Moth, *Tmetocera ocellana*, of Europe and North America, do serious damage to the unfolding flower and leaf buds of apple and other fruit trees.

The leaf-rolling Tortricid caterpillars are of less economic importance than the fruit miners.

Species of *Cacœcia* attack fruit and shade trees in North America. Species of *Ancylis* have so-called "leaf-tying" caterpillars which fold or roll together leaves of strawberry, apple, and other plants. *Capua coffearia* rolls the foliage of the tea plant in Ceylon.

The Moth Borers or **Pyralidæ** form a family of small moths with long narrow forewings, whose slender caterpillars live concealed either as borers in stems or fruits, or below ground among decaying leaves or bark, or within the shelter of rolled leaves. A large number feed upon cultivated plants, and several upon grain, flour, etc.

The majority of the smaller moths in grass or which come to light are Pyralids, but they are readily confused with small Noctuids or with large Tineids.

The caterpillars agree with Tineid caterpillars in having a complete circle of hooks on the sucker feet, whereas in the caterpillars of other moths the hooks are in two opposed series on the sucker feet.

The caterpillars of *Ephestia kuehniella*, the **Mediterranean Flour Moth,** feed on flour, bran, biscuits, cereal foods. Each caterpillar feeds within a silken tube and spins silk wherever it goes, especially when travelling about before pupation. The food medium thus becomes matted together, and in flour mills the machinery may be fouled by such silken webbing.

Similar habits are possessed by *Plodia interpunctella*, the Indian Meal Moth, another cosmopolitan pest, and by *Pyralis farinalis*, the Meal Snout Moth.

The most effective control measure against these flour moths is the fumigation of the infested mill or warehouse with chloropicrin or hydrocyanic acid, or sterilisation by steam heat.

Of the leaf-rolling Pyralids, one of the more important is *Sylepta derogata*, the Cotton Leaf-roller of India, Africa, and Java.

The most important Pyralid pests, however, are those whose caterpillars tunnel in plant stems.

The **Sugar Cane Moth Borers** *Diatrœa* and *Chilo*, cause great damage in this way in sugar cane growing regions.

*Diatrœa saccharalis* is the most important enemy of sugar canes in Mexico, the West Indies, and the United States. The eggs are laid in clusters upon the leaves, and the emerging caterpillars gnaw their way into the stalks of the cane, kill the central shoot of the young plant, and produce the so-called

"dead heart" condition. In the Southern United States the caterpillar is often termed the Larger Cornstalk Borer, but the latter pest is now considered to be a distinct species, *Diatrœa zea colella.*

*Chilo simplex* is the Sugar Cane Borer of India, attacking, in addition to sugar cane, such plants as corn, sorghum, rice, and millet.

*Polyocha saccharella* is the Cane Root Borer of India.

Another boring Pyralid of great importance is the **European Corn Borer,** *Pyrausta nubilalis,* whose introduction and establishment within the United States is causing great alarm there.

This pest has a wide climatic range, being found over practically all of Central and Southern Europe, and has been recorded from Western Asia, Siberia, Northern India, the Philippine Islands, and Japan. The larvæ, whilst preferring maize, can thrive on a host of other plants—millet, hops, hemp, broomcorn, sunflowers, mugwort, pigweed, rhubarb, field root crops, small grain. The eggs are laid on the food plant; the emerging larvæ feed on the tender foliage and eventually enter by a mid-vein and tunnel into the stem; with maize they enter the developing ear.

The adult is a strong flier, and distribution is effected through the flight of adults and influenced by prevailing winds. In the United States, where the corn borer was introduced probably in 1910 from Italy on broomcorn, the area of distribution has increased from 100 square miles, in Massachusetts, in 1917 to 93,786 square miles in 1927. At present the infestation occurs in regions such as Ontario, New England, Ohio, Michigan, and North-Western Pennsylvania, where corn growing is of little importance as compared with its status in the great corn belt; but the spread of the insect into the great corn-growing States seems inevitable.

A very large number of parasites have been introduced from Europe and liberated in the infested areas, and some appear to have established themselves, although their ultimate effect upon the degree of infestation cannot as yet be estimated.

The Powder Post Beetles, or **Lyctidæ,** are small, cylindrical, reddish-brown beetles, both larval and adult stages of which lie in dry wood, either in cylindrical tunnels or just below the bark. The interior of an infested piece of timber may be reduced to powder before the presence of the beetles is discovered.

*Lyctus brunneus* and *Lyctus linearis* are widely distributed

over the world ; the female beetle lays her eggs in the pores of the cut surface of hardwood timbers, and the larvæ tunnel in the sapwood in a direction parallel to the fibres ; only dry timber such as old stumps and posts, furniture, tool handles, railway sleepers, and so forth are attacked. These species are among the most harmful of timber pests.

The **Bostrychidæ** are somewhat small beetles, similar in appearance to the *Anobiidæ* and *Scolytidæ*, but distinguishable from the former beetles by the more cylindrical shape and the imperfect separation of the first tarsal joint from the second, and distinguishable from the latter beetles by the *rounded* and prominent eyes, and by the loosely jointed club of the antenna as contrasted with the oblong eyes and compact antennal club of the *Scolytidæ.*

The larvæ and adults of these beetles bore tunnels in cut timber and dried wood. In tropical countries, bamboo boring species cause considerable damage. Some species attack growing fruit trees.

The Furniture Beetles, or **Anobiidæ,** constitute a family of some 1,400 species of small brown or black beetles whose larval stages are small white, fleshy grubs similar to White Grubs, but much smaller. Both adults and larvæ are feeders on dried organic material, such as timber, furniture, books, tobacco, drugs, dried fruits, cereals.

*Anobium punctatum*, *Xestobium rufovillosum*, and *Ptilinus pectinicornis* all occur commonly in old furniture and in old timbering of buildings, and may cause, over a long interval of time, very serious damage. In several cases in Europe the timbering of ancient buildings has had to be replaced owing to the ravages of these beetles. Westminster Hall, in London, whose rafters dated back to the time of William Rufus, affords a case in point.

The term " death watch beetles " applies strictly to the second species mentioned, and refers to a peculiar tapping noise, a mating call, made by both sexes after the emergence from their pupal cells within the timber. The round exit holes made by the emerging beetles are characteristic features of the surface of furniture or timber that has been attacked.

*Lasioderma serricorne* and *Sitodrepa paniceum* are cosmopolitan Anobiids which injure stored products, the former species frequenting more particularly cigarettes, cigars, drugs, the latter species being found to attack biscuits, flour, drugs.

*Niptus hololeucas*, a small spherical silky-brown beetle, and *Ptinus fur*, a similar form, attack household provisions, drugs,

books, furs. *Gibbium scotias*, a blood-red mite-like creature, feeds upon the paste of wall-paper and book-bindings.

The Flat-headed Borers, or **Buprestidæ,** are somewhat large, brilliantly coloured beetles, primarily inhabitants of the tropical rain forest. The larval stages are plant tunnellers, and are distinguishable from all other beetle larvæ by the small, flat head, the greatly swollen prothorax, and the slender hind body, which gives them a characteristically club-shaped appearance.

The larvæ occur in broad galleries beneath the bark of trees or in the stems of herbaceous plants, all, in a few cases, between the surfaces of a leaf.

*Chrysobothris femorata* is the Flat-headed Apple-tree Borer of North America. *Sphenoptera neglecta* is the Cotton Stem Borer of Africa, *Sphenoptera gossypii* that of India.

The Round-headed Borers, or **Cerambycidæ**, are forest-frequenting beetles provided with very long antennæ, and for this reason often referred to as Longicornes or Longhorn Beetles. In shape they are usually rectangular, with parallel sides, and they have a distinct spur on each tibia.

The adults are foliage feeders, but the yellowish, tapering larvæ are tunnellers in the trunks or branches of trees, or burrowers just below the bark. A few genera, such as *Saperda*, tunnel the stem of herbaceous plants, but most species attack only dead or dying trees.

*Saperda candida*, the Round-headed Apple-tree Borer, is second only to the Codling Moth as an apple pest of North America.

The Shot-hole Borers, or **Scolytidæ,** are small cylindrical beetles similar to weevils in appearance, but distinguishable by the absence of snout and by their habits.

Nearly all are borers in woody tissues, only a few species being known to attack herbaceous plants. The tunnels occur between the bark and wood of a tree, and are constructed on a complex pattern which is usually distinctive of the species of beetle that has made it.

There are monogamous and polygamous species. With the first named, the initial tunnel is made by the female before mating; after mating she makes a number of lateral tunnels at right angles to the first one, laying an egg at the end of each; the male remains in the original tunnel. The tunnels are generally in one plane, between bark and wood.

In the case of polygamous species, the first tunnel is made by the male; the females gather within it and make each a tunnel from it; from this secondary tunnel, again, each female makes a number of tunnels in which to lay her eggs.

In both cases the hatched larva bores farther along the egg tunnel, and eventually burrows outwards to the surface in order that the emerging beetles may escape.

In some forms, the so-called "ambrosia beetles," the galleries contain the fungus *Ambrosia*, which the insects cultivate and use as food.

*Xyleborus dispar*, the "Shot-hole Borer," attacks fruit and forest trees in Europe. *Scolytus* (*Eccoptogaster*) *rugulosus* is the Fruit Bark Beetle of Europe and North America. *Xyleborus fornicatus* is the Shot-hole Borer of tea in Ceylon and Assam.

The Spruce Bark Beetle, *Ips typographus*, is one of the most dangerous bark beetles in Europe; both adults and larvæ bore into the bark and sapwood of conifers, particularly of spruce.

Other dangerous bark beetle genera are *Scolytus*, *Hylastes*, *Hylesinus*, *Hylurgus*, *Cryphalus*, *Tomicus*, *Xyleborus*, and *Dendroctonus*. The last-named genus is the forest bark beetle of North America and comprises some ten economically important species.

The control of bark beetles is difficult, but cutting and barking of infested trees and burning of the bark during winter or early spring are measures usually adopted.

The Pulse Weevils, or **Bruchidæ,** are small, thick-set, hairy beetles whose larval stages occur within the seeds or seed pods of leguminous plants. Usually they eat out the starchy portion of the seed but avoid the germ.

*Bruchus pisorum* is a cosmopolitan pest of growing peas, dried peas not being attacked. *Acanthoscelides obtectus*, on the other hand, readily attacks dried beans.

The Gall Midges, or **Cecidomyiidæ,** are minute, delicate flies possessing long antennæ with whorls of hairs at the joints, long slender legs, and rather broad, heavy wings whose veins are few and weakly developed. The larval stage is a small-headed pink maggot, tapering slightly at each end, possessing fourteen body segments instead of the usual thirteen, and having a little horny hook on the ventral surface of the segment immediately behind the head, termed the "anchor process"; it is used for locomotor purposes and for smashing up the substance of the plant gall within which the larva may live.

The majority of the gall midges spend the larval stages within galls produced by the proliferation of injured plant tissue, but many forms live within the stems of plants.

The **Hessian Fly,** *Mayetiola destructor*, is probably the major

cereal pest of the North American wheat and barley growing areas. It is an importation from Europe and is believed to have been introduced in straw when Hessian troops landed in Long Island during the Revolutionary War. The larval stages occur within the plant stem or between stem and leaf sheath (Fig. 30), and there also they pass the winter as a hard puparium similar to a flax seed. They are thus readily transported in infested straw.

The only practicable method of avoiding the ravages of Hessian Fly is that of delaying the sowing of the crop until the flies are no longer on the wing. This "fly-free date," as it is called, varies in date according to latitude, longitude, and altitude, but in most of the North American areas where winter wheat is grown the date falls between 10th September and 1st November.

Delayed sowing is, of course, only a precaution against the autumn brood of Hessian Fly. The crop is still liable to infestation in the spring from the main brood, which may come from neighbouring infested fields or from self-sown wheat present at the time of the autumn sowing.

One of the most destructive enemies of the pear tree in Europe and North America is *Contarinia pyrivora*, the **Pear Midge,** whose larvæ tunnel into the young fruit and cause shedding. Another Cecidomyiid introduced from Europe into North America is the **Wheat Midge,** *Diplosis tritici*, whose larvæ attack the maturing head of the wheat plant.

The Root Maggot Flies, or **Anthomyiidæ,** are flies somewhat of the house-fly type, but differing from the true house-fly, *Musca domestica,* in that the fourth longitudinal vein of the wing is straight and does not turn forwards to meet the third vein and make an enclosure or cell as it does in true Muscids.

The larvæ are maggot-like, but usually possess four rows of thread-like processes on the segments.

The adult flies are flower haunters, except for a few predacious species, but the larvæ vary in habit, some tunnelling in dung, others in decaying vegetable matter, others in the roots of living plants.

The root burrowers include particularly *Phorbia cepetorum*, the Onion Fly, whose maggots burrow into the onion bulb in Europe and North America ; *Chortophila brassicæ*, the Cabbage Root Fly, which attacks the rootlets of cabbage and cauliflower in the same area ; *Pegomyia betæ*, the Beet Leaf Miner, makes galleries between the surfaces of beet foliage in Europe ; *Hylemyia coarctata* is the Wheat Bulb Fly of Europe and Northern Asia.

The Fruit Flies, or **Trypetidæ,** are flies of moderate or rather small size, marked usually with bands of yellow or brown, and with wings usually mottled or with dark bands. They constitute a family of the so-called *Acalyptrate Muscidæ*, that is to say, flies with the general appearance of the house-fly but lacking the *squamæ*, the scale-like structure posterior to the base of each wing.

In the usual fruit fly life-cycle, the eggs are inserted just under the skin of a fruit by the long horny ovipositor of the female; the larval stages tunnel in the fruit; after about a fortnight they are full fed, whereupon they leave the fruit, fall to the ground, burrow therein, and pupate. The majority of the fruit fly pests of cultivated fruits belong to the genera *Ceratitis* and *Dacus*.

*Ceratitis* is a genus with dark banded wings, and with the thorax and wing bases spotted with black.

*Ceratitis capitata*, the **Mediterranean Fruit Fly,** is indigenous probably to West Africa, but is now established in Europe, Asia, Africa, Australia, and Hawaii, but not, fortunately, in the North American fruit-growing areas. It is one of the most serious dangers that the fruit industry is liable to meet, and has already destroyed the commercial production of fruit in several areas. Its establishment in the United States would be a calamity to the fruit-growing industry there.

It is a yellow fly about the size of a house-fly, with red eyes, and with the wings crossed by two irregular brownish-yellow crossbands and possessing a brownish-yellow base.

The glistening white eggs are placed beneath the skin of a ripe fruit (Fig. 29), and the larvæ feed in the pulp for two or three weeks. Then they leave the fruit and pupate in the ground, remaining there for twelve to twenty-one days. Unripe citrus fruits are usually protected to some extent by the essential oils of the rind which are toxic to the eggs, although no fruit juice is sufficiently acid to inhibit the development of the larva; ripe citrus fruits are readily attacked.

The eggs and larvæ are fatally affected by cold storage temperatures, failing to survive refrigeration at 40°-45° F. for three weeks, or 32°-35° F. for two weeks.

Control measures comprise the clearing up and destruction of fallen fruits; the protection of trees with netting; the use of arsenically poisoned syrup as a poison bait spray; the cold storage of fruit. In Hawaii the establishment of certain Hymenopterous parasites, notably *Opius humilis* from South America and *Diachasma tryoni* from Australia, is being attempted.

Of the species of *Dacus*, the best known is *Dacus cucurbitæ*, the Melon Fruit Fly of India, Ceylon, Hawaii, which feeds on cucurbitaceous fruits; and *Dacus ferrugineus*, the Mango Fruit Fly of India, Ceylon, Java, and the Philippine Islands.

*Dacus oleæ*, the Olive Fruit Fly of the Mediterranean countries and India, does enormous damage to olives.

The genus *Rhagoletis* includes *R. pomonella*, the Railroad Worm of apples in North America; *R. cerasi* of Europe, *R. cingulata*, and *R. fausta* of North America, all infest cherries.

*Anastrepha* is a South American genus with several destructive species.

*Bactrocera* (*Chætodacus*) *tryoni* is the Queensland Fruit Fly of Oriental and Australasian countries.

*Acidia heraclei*, the Celery Fly of Europe and Asia Minor, occurs in the larval stage as a leaf miner of celery, parsnip, and parsley.

The Grass Stem Maggot Flies, or **Oscinidæ,** are yellow or yellow and black Acalyptrate Muscids, minute in size, and occurring commonly among grasses. The larvæ live generally within the stems of grasses, but some are leaf miners and others inhabit galls on grasses.

*Oscinis theæ* mines the leaves of the tea plant in India.

*Oscinella frit*, the Frit Fly, is a stem tunneller of cereals in Europe and the United States.

*Chlorops tæniopus*, the Gout Fly, is a stem miner of wheat, rye, and barley in Europe.

The Stem Saw-flies, or **Cephidæ,** are small, slender, narrow-bodied insects whose larvæ, which somewhat resemble limbless caterpillars, live within the stems of plants. In Great Britain the best known is *Cephus pygmæus*, which tunnels in the stem of the wheat plant. In North America, *Cephus occidentalis*, the Western Grain Saw-fly, has similar habits.

The Gall Wasps, or **Cynipidæ,** are again widely distributed. The larvæ live and feed within a "gall," a mass of proliferating plant tissue induced by the presence of the living larva. Eighty-six per cent. of the known species of Cynipidæ have been reared from galls on species of the oak; another 7 per cent. are confined to species of *Rosa*, and the remainder occur particularly on Compositæ. The family is one of intense interest to the biologist, and the reader should refer to the work of Adler for a full account of Cynipid biology.

A certain number of mining forms occur within the group Chalcidoidea, a very extensive superfamily of minute Hymenoptera, the majority of which are parasitic in the egg, larva, or

pupa of other insects. There are many phytophagous forms, placed usually in the family *Eurytomidæ*. Some species produce galls at or near the joints of cereal and grass stems, and are therefore known popularly as "joint worms." Thus *Harmolita tritici* attacks wheat in Europe and North America. *Harmolita grandis*, the Wheat Straw-worm of North America, has two alternating generations, one termed *minutum*, which attacks wheat in the spring and deforms the stem, the other termed *grandis*, which destroys the embryonic heads of the wheat.

Other species live within seeds. Thus *Bruchophagus funebris* lives within the seeds of clover and alfalfa; *Euoxysoma vitis* within grape seeds; *Megastigmus spermotrophus* within the seeds of the Douglas fir.

The **Blister Mites** are not insects, strictly speaking, but members of the Arachnoid family *Eriophyidæ*. They are minute, elongated creatures with only two pairs of short, stumpy legs.

*Eriophyes ribis*, the Currant Gall Mite, produces a swollen condition of black currant buds, all stages of the mite being found within an infested bud; it is a serious pest of currants in Europe.

*Eriophyes pyri* lives beneath yellow blisters, like galls, on the foliage of pear and apple in Europe and North America; the winter is passed beneath the bud scales.

*Eriophyes gossypii* infests cotton in the West Indies, causing blisters on the leaves.

# CHAPTER XVI

## INSECT PESTS: The Life-Cycle

It may be laid down as an axiom of Applied Entomology that effective control of an insect pest cannot be hoped for until an accurate and comprehensive conception has been established concerning the four groups of data which deal respectively with the **life-cycle,** the **distribution,** the **behaviour,** and the **mortality factors** of the pest under review.

The term **life-cycle** refers, strictly speaking, to the whole period of time elapsing between the fertilisation of an egg, and the ultimate death of the insect which develops from that egg. Since, however, the longevity of an insect is difficult to estimate, even approximately, and the period of time between fertilisation and deposition of an egg is again difficult to estimate, the life-cycle as referred to by the entomologist comprises more usually the number of days elapsing between the point of time when an egg is laid and the attainment of sexual maturity of the resulting insect; or it may even refer only to the period of time between the emergence of the insect stage from the egg and the emergence of the immature insect stage from the so-called pupal condition. Using the term in its fullest sense, however, the life-cycle may be said to comprise three periods, namely :—

(1) The duration of the egg stage between fertilisation and hatching, that is to say the **embryonic period.**

(2) The duration of the period between emergence from the egg and attainment of sexual maturity, that is to say the **prematuration period.**

(3) The duration of the period between attainment of sexual maturity and death, that is to say the **maturation period.**

In a large number of insects, grouped generally as **hemimetabolous** insects, the prematuration period comprises a number of phases, all actively feeding—that is to say, **trophic** phases—demarcated one from the other only by the skin moults necessitated by continuous growth, and by increasing development of wings and sexual glands up to the condition characteristic of the *imago* or adult insect.

That is to say, the phases are merely growth phases of one

stage, the **nymphal stage,** and the nymphal stage is an immature, stumpy-winged replica of the adult.

In the majority of the other insects the so-called **holometabolous** insects, the prematuration period consists of several stages which may differ from one another very considerably, morphologically and biologically. The egg stage is succeeded by an active, trophic stage—the **larva**—very different in appearance from the imago, but representing a nymph in which the wing buds are developing internally instead of externally. There may be a succession of growth phases of this stage, the so-called larval instars. Then succeeds an actively mobile but non-trophic **prepupa** which passes eventually into the relatively quiescent **pupa.** The pupa again differs considerably from larva or imago. Within the pupal integument the tissues break down and are reorganised, and finally there emerges from it the immature but fully winged imago.

Thus, if the larva represents a series of trophic nymphal phases, the pupa can be looked upon as representing a telescoped series of quiescent, non-trophic nymphal phases. The meaning of this quiescence will be discussed later.

Now the actual duration of an insect life-cycle is not a period of time constant in length for each individual of the species. The average length of life-cycle of a species under certain conditions can be estimated, but the life-cycle may be affected by physical factors, notably by temperature and moisture, so that the life-cycle of the individual may be longer or shorter than the average, according to the acceleration or retardation produced by physical factors upon the rate of metabolism. If one or more of the life-cycle stages be lengthened or curtailed, the total length of the life-cycle is not necessarily altered likewise. It is so affected in very many insects certainly. Thus, for example, the life-cycle of the house-fly is shorter in Southern Europe than in Northern Europe, owing probably to differences of mean summer temperature. It has been shown that in the case of the bean weevil, *Acanthoscelides obtectus*, a lowering of the temperature by so small an amount as 10° F. can double the duration of the life-cycle.

In many forms, however, the normal rhythm of existence is apparently so fixed by heredity that a shortening or lengthening of any stage is compensated by an inverse alteration of the succeeding stages. Thus, for example, Baumberger has shown that in the life-cycle of the Oak Eggar Moth, *Lasiocampus quercus*, when the length of the caterpillar stage was reduced gradually from the normal 245 days to 112 days by refrigeration

methods and by judicious selection of precocious larvæ, the pupal stage always lengthened accordingly, so that the average length of the whole life-cycle remained unaffected by temperature changes.

A considerable accumulation of data is available concerning the effect of temperature upon the insect life-cycle. There would seem to be for each species of insect a range of temperatures between whose maximum and minimum extremes the insect is active; beyond either extreme, metabolism is retarded and dormancy or death may happen to the insect, according to the degree of temperature and according to the length of exposure to this temperature.

This range of temperatures may be termed the range of **Effective Temperatures,** and the point upon it at which metabolic activity is greatest may be termed the **optimum temperature.**

Similarly there is for each species a range of **Effective Humidities,** bounded by maximum and minimum limits of metabolic activity and having upon it an optimum point. Probably also, there are ranges of effective atmospheric pressures, light intensities, wave lengths, atmospheric oxygen content, and so on

Thus for any given insect there are definite boundaries of temperature, humidity, and so on, which limit metabolism, activity, and development. There is, for example, a temperature below which life is impossible even for a moment—the **infra - minimum temperature.** Similarly there is an **ultra-maximum temperature** at which, and beyond, death is instantaneous. Similarly, absolute dryness, that is to say **infra-minimum humidity,** is prohibitive of life, and so is **ultra-maximum humidity** or saturation, although insects can withstand extremes of humidity better than extremes of temperature.

The minimum effective temperature for insects generally is considered to be round about 5°-6° C., and the infra-minimum temperature may be as low as 10° below zero centigrade. Insects, however, are very resistant to low temperatures. At the infra-minimum temperature, death is probably caused through crystallisation of the body fluids, and when this occurs a certain amount of heat is given off and the internal temperature of the insect rebounds upwards for several degrees. The temperature at which crystallisation occurs is termed the **undercooling point.** The highest point of the rebound is termed the **freezing point.** It has been asserted by earlier workers, notably Bachmetjew, that if the insect is then restored to

normal temperature it will revive after an interval dependent upon the length of time it has been undercooled, but that if the insect be undercooled a second time it will die. Such a fact would explain the tendency for frosts in late spring or following a spell of mild weather, to cause great mortality among insects, when similar mortality has not been caused by more severe frosts earlier on. Recent work, however, by American and European entomologists suggests that a great many species of insects cannot survive even a single undercooling. It has been shown that certain insect species which are able normally to endure long periods of dormancy at low temperatures are killed when their tissue fluids freeze, and that other species can endure such freezing. The freezing point of the tissues of an insect, further, may be lower after a spell of subjection to low temperatures, a hardening process so to speak, than if following a period of subjection to high temperatures such as those of late spring or summer. That is to say, the gradual approach of cold weather "hardens" insects accustomed to hibernate during winter and enables them to withstand very low temperatures, but in the case of insects not accustomed to hibernate, dormancy and eventual death may occur after exposure to comparatively high temperatures. Thus, according to the American entomologist, Robinson, the grain weevil *Sitophilus oryzæ* becomes dormant at 7·25° C.; its fellow-species *Sitophilus granarius* becomes dormant at 1·6° C.; *oryzæ* dies after seventeen days of such dormancy; *granarius* dies after thirty-eight days of such dormancy. These weevils do not hibernate normally, and exposure to low temperatures, instead of hardening them, makes them more susceptible to dormancy and death. The moisture content of their medium, however, influences the degree of susceptibility to low temperatures. They are more susceptible if the grain is damp and if it is absolutely dry.

In an insect's tissues, water exists partly in a free condition and partly in a bound condition, that is to say adsorbed by the colloids and occurring as thin shell around each colloid particle.

The phenomenon of hardiness in certain insects is apparently bound up with this condition of affairs; the greater the proportion of bound water to free water, the greater the ability of the insect to withstand low temperatures, since such bound water will not freeze at temperatures higher than 5° below zero Fahrenheit (–20° C.) and can undergo considerable compression; in certain insects, apparently, subjection to gradually decreasing temperatures stimulates the conversion

of free water to bound water, and the insect becomes hardy; in other insects the converse occurs and subjection to decreasing temperature renders the insect more susceptible.

Although low temperatures may not be immediately fatal to insect life, they always impede development, so that low temperature storage is an excellent method of protecting stored goods against the ravages of insect pests. Injury by clothes moths to furs, woollens, carpets, can be minimised by storage at 40° F. Damage to peas and beans by weevils can be retarded by storage at temperatures as high as 64° F.; tobacco similarly may be freed from the tobacco beetle *Lasioderma* better by exposure for three weeks to a temperature of 3° or 4° C. below zero than by exposure to heat, as heat treatment darkens the tobacco and makes it brittle; rice, infested with *Sitophilus oryzæ*, is sterilised preferably by exposure to low temperatures than to high ones, since heat cracks the enamel of the seed and spoils the rice for milling.

Low temperatures, again, are useful in sterilising fruits; the susceptibility of eggs or larvæ of the Mediterranean Fruit Fly to low temperatures is very important from the point of view of ship transit of fruits from infected areas to countries where the entrance of such fruit is restricted.

The ultra-maximum temperature, the temperature which will kill an insect instantly, is about 60° C. for most species. A moderately high temperature, however, if applied for several hours, is usually as effective as a much higher temperature applied for a shorter time. The following pests of stored products are destroyed instantly at the following temperatures:—

*Acarids*, 150° F. for one hour; pea and bean weevils (*Acanthoscelides*), 146° F. for fifteen minutes; weevils, in general, 122° F.; larder beetles (*Dermestes*), 140° F. for an hour; furniture beetles (*Anobium*), 130° F.; insects infesting flour mills, 118°-125° F. for several hours.

Heat as a sterilisation agent for stored products is, at present, as regards large scale work, used chiefly in:—

(1) the treatment of cotton seed in Egypt against the hibernating larvæ of the Pink Bollworm, *Pectinophora gossypiella*;

(2) the treatment of flour mills in U.S.A. and Canada against the various pests of flour and grain, notably against the Mediterranean Flour Moth, *Ephestia kuehniella*.

In Egypt, since 1912, when the presence of the Pink Bollworm began to be a serious factor in cotton cultivation, much experimental work has been carried out with methods of seed sterilisation devised to kill the larvæ hibernating within the

seed. In the Sudan, infected seed can be sterilised quite effectively by exposure to sun heat; but in Egypt, sun temperatures are not sufficiently high, and sterilisation is carried out by some type or other of hot air machine, which each ginnery is compelled by law to install.

The difficulty in high temperature treatment is to decide upon the range of temperatures non-injurious to the seed but fatal to the contained larvæ; it would seem that to kill the larvæ instantaneously, a minimum temperature of 140° F. is necessary, but five minutes' exposure to a minimum of 124° F. is just as effective. As regards the seed, wet seed can be raised to 140° F. and dry seed to 150° F. without impairing germination.

The use of high temperatures for sterilising cereal mills was first suggested and successfully attempted by Dean, of the Kansas Experimental Station, during 1910-13. The use of hydrocyanic acid gas, whilst efficacious against most insects, has never been known to give complete satisfaction against the Flour Beetle (*Tribolium spp.*), the "cadelle" (*Tenebrioides*), and the Saw-toothed Grain Beetle (*Silvanus surinamensis*). On the other hand, all stages of cereal insect pests are killed by one or two hours' exposure to a temperature of 122°-131° F.

Such temperatures can be obtained in a mill by steam pipe radiation, one square foot of radiating surface being usually sufficient to heat 50-100 cubic feet of space at a steam pressure of 25-50 lbs. It is necessary to heat the mill to a temperature higher than actually required, in order to allow for inequalities in the distribution of the heat. Only one treatment per year is required, no preliminary cleaning is necessary, and the method is non-injurious to operator and property.

Maximum and minimum limits to insect activity and development occur in both the ranges of temperature and humidity. The effect on the insect is a combination of temperature and humidity influences, and since maximum, minimum, and optimum points of temperature for an insect stage will vary according to the humidity value, these points upon a graphical figure, expressing the correlated influence of temperature and humidity upon insect metabolism, will appear as curves, and the range of temperature between successive curves may be referred to as **zones of metabolic activity.** Thus, starting from the curve of infra-minimum temperatures, as the temperature increases, a longer and longer period of exposure will be required to kill the insect, until a curve of temperature points will be reached at which life continues indefinitely. The range of temperatures between the two curves may be

termed, using the nomenclature of Dwight Pierce, the **Zone of Low Fatal Temperatures.** Again, between the upper extreme of this zone and the curve of minimum temperatures there will occur a **Zone of Inactivity.** At the lower margin of this zone complete dormancy will characterise the insect, but as the temperature increases the increasing rate of metabolism will bring about a gradual approach to sensibility, followed by movement, followed by the necessity for feeding.

Above the curve of minimum temperatures, activity is at first sluggish but increases with temperature until the so-called "optimum" is reached, beyond which the rising temperatures are accompanied by less and less activity, and are finally accompanied by stupor. At the curve of stupor a second **Zone of Inactivity** commences. As the temperature increases, the sleep becomes more and more sound until a curve occurs at which death comes after long exposure. At this curve begins the **Zone of High Fatal Temperatures,** at which death occurs after shorter and shorter periods of exposure until it is instantaneous at the ultra-maximum temperature.

Humidity may affect the insect by bringing about variations in the amount of free water, at any rate in insects which do not take in water and whose free water depends upon the liberation of bound water. The American observer, Headlee, has attached importance to the **water optimum,** that is to say to the amount of body fluid which permits the maximum of metabolic reaction, the necessary chemical and physical changes, to take place. For example, if the amount of body fluid be above the optimum, a dry atmosphere will remove the surplus and so speed up the rate of metabolism, whereas a saturated atmosphere by impeding evaporation from the body surface would slow down the rate of metabolism and thus prolong an egg or pupal stage. Similarly, if the body fluid were just about the optimum, dry air would reduce it below that point and decrease the rate of metabolism, whereas moist air by impeding evaporation would permit the water content of the life-cycle stage to rise toward the optimum and so increase the rate of metabolism.

Such a view explains the discrepancies in the responses of different insect species or different stages of the one species to the same degree of atmospheric humidity. For example, laboratory experiments made by Headlee indicated that the rate of metabolism in pupæ of the Bean Weevil (*Acanthoscelides obtectus*) and the Angoumois Grain Moth (*Sitotroga cerealella*) varies *inversely* with the atmospheric humidity; in the adults

of the former it varies *directly*, in the adults of the latter it varies *inversely* with the humidity ; in the larvæ of both types the rate varies *directly* and in the egg stage *inversely* with the humidity.

A view that has gained considerable support from entomologists during recent years is the conception, borrowed really from the work of European botanists, that the passage from one life-cycle stage into the next stage will only occur when the mean daily temperatures have reached a certain sum total, the particular total being necessary to the particular stage. This sum total may be termed the **Total Effective Temperature** for that particular stage.

It must be noted that in the case of insects, when summing up the daily temperatures, only the excess of temperature above the minimum effective temperature should be taken into consideration. Further, if the value of the total effective temperature is to hold good for both winter and summer, a temperature curve must be obtained for the species based upon the observation of a considerable number of individuals kept at different constant temperatures, or, better still, at temperatures having a daily variation with constant maximum and minimum, and with fairly constant humidity conditions. With such a curve plotted it is possible to give each degree of temperature a definite value in relation to the accumulation of temperature necessary for any stage of growth or activity at the optimum temperature. Thus, suppose the optimum temperature for an egg stage happens to be 30° C., at which temperature, let us assume, the egg stage has a duration of twenty-five hours, then each hour at 30° C. has a value of 4 per cent. of the whole. If thirty hours are required at 25° C., then each hour at 25° C. has a value of 3·3 per cent. of the whole, and so on, each hour having some percentage value less than that of the optimum and dependent upon the hourly mean temperature. A table for the value of each degree between the optimum, minimum, and maximum effective temperatures can be constructed, and, using these values, the true total effective temperature has been reached when an accumulation of 100 has been obtained.

It has been assumed by some authorities that the product of the duration of a stage multiplied by the number of degrees centigrade at which development of the stage occurred, is a constant.

That is to say, that $DT = K$, where D is the duration in hours, T is mean hourly temperature in degrees centigrade, and K is a constant expressed in degree-hours, or developmental units, if we follow the nomenclature recently suggested by Shelford.

The equation will approximate more towards accuracy, however, if it be expressed $D(T - t) = K$, where $t$ is the minimum

effective temperature below which metabolism is dormant. Even thus the equation probably holds good only for a very limited range of temperatures lying on either side of the optimum effective temperature.

Further, values of D must be used that have been obtained under conditions approximating as nearly as possible to normal outdoor conditions of humidity and air currents and sunshine. The interest of the equation lies in the possibility of predicting from it whether an insect pest, whose duration of life-cycle is known under the conditions prevailing in one area, could establish itself under the conditions existing in an area that is as yet free from it.

The formula could also be employed in estimating the probable date when a generation of an insect, whose date of oviposition is known, will appear on the wing, or in estimating the probable date of oviposition, and thus the date of arrival into an area, of a generation whose initial date of appearance on the wing has been noted.

No pretence of absolute accuracy, however, can be claimed for it, since the rate of development of any life-cycle stage is influenced by other factors in addition to temperature. The theory may be used with a fair degree of safety if the insect concerned is in its native locality and if the temperatures at which its stages are developing do not lie outside a range of 5° C. on either side of the optimum effective temperature. Outside this range, such factors as abnormal humidity, precipitation, air currents, temperature variation, variations in vitality of individuals or of successive generations, and so forth, will affect the conclusions.

The relationship between temperature and the phenomena of hibernation and æstivation remains to be discussed.

The ability of some insects, especially Lepidopterous larva and pupæ, to withstand low temperatures is well known, and it has been suggested that this ability may be associated to some extent with the habit of periodical hibernation indulged in by insects of temperate zones. If the insect before hibernation or æstivation loses 30 per cent. of its gross weight by loss of water, as Tower asserts is the case with the Colorado Potato Beetle (*Leptinotarsa decemlineata*), its tissues can possibly withstand more severe extremes of temperature than if the protoplasm were not thus condensed. It may be noted that hibernation is apparently lacking from the life-cycle of tropical insects or the life-cycle of insects which are able to propagate wherever favourable conditions exist.

Temperature, however, is not the only factor conducive to

hibernation. Many species commence to hibernate before any marked fall in temperature occurs. Tropical insects and non-hibernating insects cannot be induced to hibernate by application of low temperatures ; they become torpid, it is true, but they regain their activity when the temperature is raised. Tower was able to keep the Colorado Potato Beetle in hibernation for eighteen months at a high temperature, if the atmosphere were sufficiently dry. A similar effect of drought has been shown to occur in autumn broods of the Hessian Fly (*Mayetiela destructor*). Such facts, namely, that extreme drought and extreme cold conduce towards hibernation certainly support the possibility of this phenomenon being prefaced by a reduction of body fluid in the insect.

Rouband, the French biologist, discussing the questions of hibernation, and retardation of the life-cycle, among Muscid flies, postulates two causes for such retardation :—

(1) Low temperature (athermobiosis) or low humidity (anhydrobiosis), which, in one physiological group, the *homodynamic* flies, exemplified by *Musca domestica* and *Stomoxys calcitrans*, influence all the generations of the year ; that is to say, homodynamic flies can produce a rapid succession of generations throughout the year if conditions of temperature and humidity be suitable ; should these conditions be unsuitable, the flies remain dormant until conditions improve.

(2) Uræmic intoxication (asthenobiosis), occasioned by a progressive inability, increasing from generation to generation, for the Malpighian tubules to eliminate the uric excretory products, so that these accumulate in the adipose tissue. At the end of a number of generations which can be retarded or accelerated by temperature or humidity, this degree of intoxication eventually reaches a point at which further development of the animal is inhibited. Only prolonged exposure of the organism to low temperature or to low humidity will, by reducing metabolism to a minimum, permit this accumulation of waste products to be transferred to the Malpighian tubules and so eliminated, in which case development recommences. Uræmic intoxication characterises, according to Rouband, a physiological group of flies which he terms *heterodynamic*.

That is to say, in probably very many insects whose metabolic activity is intense, hibernation or æstivation results from metabolic exhaustion brought on by an exaggerated accumulation of urates in the tissues. The prolonged exposure to cold, of hibernating insects, or to drought, of æstivating insects, reduces metabolic activity to a low ebb and enables the tissues to recuperate.

# CHAPTER XVII

## INSECT PESTS: The Distribution

The numerical abundance and potential economic status of an insect species in any particular area are dependent upon three factors, namely, the influence of climate upon the number and duration of generations, the availability of suitable food media and oviposition media, and the rate of mortality from climate, diseases, parasites, and predators. The likelihood of any extension of its area of distribution depends upon the intensity of these factors, upon its powers of transportation, and upon the existence of indirect agents of transportation. Its ability to establish itself in a new area depends again upon questions of climate, food, and enemies.

The inherent power of an organism to reproduce and survive, that is, to increase in numbers, is defined by the American entomologist, Chapman, as the **biotic potential.** In speaking of biotic potential, however, distinction must be made between **reproductive potential** and **survival potential.** Reproductive potential may be defined as the *potential* number of progeny in one season, starting with one pair of insects, and assuming that there was no prematuration mortality whatever; thus, in the case of the house-fly, *Musca domestica*, assuming an equal number of males and females, the sex ratio is 0·5; the number of eggs per female is 120; the number of generations per year under optimum conditions of physical environment is, let us say, seven; then the reproductive potential or number of flies produced during the season is $pz^n$, where $p$ is the number of flies at the beginning of the season, and $z$ is the product of the sex ratio and the number of eggs per female, and $n$ is the number of generations. That is to say, starting with one male and female fly, $pz^n = (2 \times 60)^7 = 5{,}598{,}860{,}000{,}000$ flies at the end of the season.

Survival potential may be defined as the *actual* number of descendants that survive at the end of a season; that is to say, it represents the reproductive potential minus the resistance of the environment. Thus, in an environment in which all the ecological factors were at the optimum, the survival potential would approximate in value to the reproductive potential;

in an environment in which all conditions were near the limit of toleration, the survival potential would be very much lower in value than the reproductive potential.

The fact that climatic conditions exercise some kind of control over the prevalence of insects has always been realised, but the manner of the occurrence of insect infestation and its relation to climatic conditions have never been clearly understood and have not until recently been investigated. Confusion has arisen because, although many records of climatic phenomena associated with seasonal variation in the appearance of insects have been made, they have not been based upon sufficiently accurate and authenticated observations.

One great difficulty in the interpretation of such facts as have been recorded arises from the physical inability of the few isolated investigators who have studied the subject to cover more than a small portion of the field of climatic phenomena, and the tendency, therefore, for such investigators to ascribe to a single factor the credit for predominant influence upon insect life. Thus the establishment of a single climatic factor as a standard that will express the exact measure of meteorological influence over the animal has been attempted by many writers, and among others the following factors have been put forward: *Mean Daily Temperature* above 6° C.; *Total Temperatures*; *Minimum Temperature*; *Atmospheric Moisture*; *Relative Humidity*; *Saturation Deficit.*

So far back as 1894, Merriam postulated that in North America:—

(1) Animals and plants are restricted in northward distribution by the total quantity of heat, that is to say, the sum-total of mean daily temperatures above 43° F. during the season of growth and reproduction.

(2) Animals and plants are restricted in southward distribution by the mean temperature of a brief period during the hottest part of the year.

The attraction to an investigator of this idea of a standard will be understood when it is realised that if the occurrence of the insect pest could be attributed, say, to a certain total temperature during the growing season, the whole art of insect control could be reduced to a mathematical calculation, for it would not be difficult to ascertain under given conditions the time of the year that general infestation would commence, and preventive measures could be taken accordingly.

Howard, for example, has endeavoured to show how the range of the Yellow Fever Mosquito (*Aëdes ægypti*) is determined by temperature, and how the exact limitations of the

regions in which this mosquito, if accidentally introduced, might be expected to become established, can be determined by calculating the accumulated daily mean temperatures.

Improved experimental methods, however, have indicated that in the case of many insects, probably in the great majority, the animal is influenced to a great extent by several factors acting together, so that even if it be granted that one particular factor may be more influential than the others, it is still not possible to accept any of the standards suggested, since they do not express completely the influence of a sum-total of factors. In searching for a convenient standard to indicate this complex of factors, Shelford and others have advocated the adoption of what is termed the **Evaporative Power of Air,** that is to say the total effect of air temperature, relative humidity, average wind velocity, air pressure, upon a free water surface in the shade or sun, as expressed in the amount of water evaporated. Such a standard would be convenient, since it is capable of precise measurement by an instrument termed an atmometer, which measures the number of cubic centimetres of water evaporated from a surface per hour.

The mode of operation of this complex of factors upon the metabolism would seem, according to Shelford, to be somewhat as follows :—

The body temperature of an animal, whether a "warm-blooded" or a "cold-blooded" animal, is nearly always higher during activity than the temperature of the surrounding medium. A moist, cold atmosphere (very low evaporation) will, owing to rapid conduction of heat, decrease the body temperature and *decrease* metabolism in a *cold-blooded animal* and *increase* metabolism in the case of a *warm-blooded animal* within the limits of its capacity for heat regulation. Such a heat loss is less pronounced in a dry, cold atmosphere owing to less rapid conduction of heat. In a dry, warm atmosphere (high evaporation) the rapid rate of evaporation keeps down the peripheral temperature of the animal, prevents excessive metabolism and too rapid rise of temperature, which would be fatal to a cold-blooded animal; in a warm-blooded animal the high evaporation permits regulation of the body temperature and so saves the animal from heat-stroke and death. In a moist, warm atmosphere, heat-stroke and death occur readily, owing to lack of evaporation and lack of peripheral cooling, in the case of warm-blooded animals, even if the surrounding temperature is only normal or subnormal.

Wind movement increases evaporation and encourages

radiation of body heat. The animal's body is thus cooled, and, within limits, metabolism is *increased* in warm-blooded animals and *decreased* in cold-blooded ones.

In studying the limitation of insects by climatic conditions, Hopkins has suggested, for the United States at any rate, the use of what he terms the **Bioclimatic Law.** That is to say, according to Hopkins, if the date of a periodical event, such as, for example, the date of emergence of the first Hessian Fly brood of the year, be established for one particular locality, then a corresponding date for the same phenomenon in another district can be determined by calculating a variation which is at the rate of four days for each degree of latitude, five degrees of longitude, and 400 ft. of altitude. There may be slight errors in this computation, due to topographical differences, soil conditions, and weather variations, but the amount of such error is in direct proportion to the intensity of the controlling influences, which can be measured, therefore, in terms of days, or the equivalent in degrees of latitude or feet of altitude with the computed date as a constant. In a similar way the geographical limits of an insect might be computed.

The Southern Pine Beetle (*Dendroctonus frontalis*) of the United States, for example, has two complete generations a year in the northern and highest limits of its range, but in more southerly areas may have five or more generations, the broods overlapping from late spring to early autumn. Remedial measures, consisting, generally speaking, of removal and destruction of infested bark, should be undertaken during the period when all stages of the beetle are to be found in the tree that is to say during the period between the end of autumn and the commencement of spring. This period varies according to latitude and altitude, commencing in September in the north and higher altitudes, and in December in the south towards sea-level, ending about the middle of May in the north, about the end of February in the south. The period of control possibility can, in fact, be calculated quite accurately from climatological data, and Hopkins would seem to have founded his generalisation upon data derived chiefly from observation of this type of insect. Whether the Bioclimatic Law is of general application to other types of insects and to other countries remains to be settled.

In the United States this principle is used to determine the dates of sowing wheat in areas infested by the Hessian Fly (*Mayetiola destructor*). The general method of avoiding Hessian Fly damage in the winter wheat regions is late sowing in the

autumn. The autumn brood of flies appears and disappears within about a week, so that if the date of emergence, being controlled primarily by climatic conditions, and secondarily by weather, soil, and topographical influences, can be calculated, a "fly-free" date for the sowing of wheat can be recommended for any particular district.

It may be added that the Bioclimatic Law holds very closely for the eastern climatic provinces of North America, but breaks down at the Rocky Mountains and does not account for conditions on the Pacific Coast. The climatological basis of the generalisation is, of course, the distinction between a continental climate where temperatures rise rapidly in spring and fall rapidly in the autumn because of the low specific heat of soil, and a marine or seacoast climate where the higher atmospheric humidity retards the rise of spring temperatures and the fall of autumn temperatures.

The ability of an insect to increase its area of distribution depends upon food and oviposition facilities and upon its powers of locomotion. Even an insect of feeble locomotor powers and of restricted food habits may increase its area of distribution fairly rapidly if its food resources occur in large, contiguous blocks, such as happens under conditions of large scale agriculture and horticulture.

In the great majority of insects, probably, the rate of area increase depends upon the degree of contiguity of food plants. Insects which are restricted in food habit to one particular genus or species or even family of food plants will be at a disadvantage, therefore, in this respect as compared with insects which have a wide range of food plants, unless favoured by the agricultural or horticultural practice of growing large blocks of the one kind of plant in close proximity. Similarly, an insect with sedentary or semi-sedentary habits such as a borer or a leaf miner or a gallicole, will not increase its area so rapidly as will a foliage feeder, unless favoured by the possession of a migratory phase in its life-cycle, or by possession of an active, non-trophic imaginal stage.

That such migratory phases do occur and that such phases may be aided by air currents is a well-observed fact, especially in the case of semi-sedentary insects such as *Aphididæ* and *Coccidæ*.

Lepidoptera are known to be carried upwards by convectional air currents over heated areas and to drift in swarms on prevailing winds.

The Monarch Butterfly (*Anosia plexippus*), for example, has extended its range widely over the islands of the Pacific

Ocean during the last fifty years, largely through the agency of winds.

The island of Krakatau, between Java and Sumatra, twelve miles from any other land, was completely sterilised of all life by a volcanic outburst in 1883 that covered the whole island with pumice and ash to a depth of 100-200 ft. Yet in 1921 an insect fauna of over 400 species was collected.

The most important example, however, of an extension of area by migration is afforded by migratory locusts. In the case of these insects, the general opinion has been that there is in each case a regular breeding ground in regions remote from the cultivated areas which are periodically ravaged by locust swarms. In this remote breeding ground they exist in numbers insufficient to constitute a danger to vegetation, and only during periods of abnormal rate of breeding do they mass in swarms and migrate in search of more favourable feeding grounds.

Recent work by Russian entomologists has somewhat modified this view. The migratory locust of South Europe, *Locusta migratoria*, is now to be regarded as a swarm phase of a form, *Locusta danica*, formerly regarded as a separate species, which is a non-migratory form. Apparently both forms can be bred from the same egg mass, laid by a single female, and can be changed one into another by altering the conditions of breeding. Similar evidence, brought forward by Faure, has shown that *Locustana pardalina* in South Africa also possesses two phases, and that the solitary or non-migratory phase which mingles with the swarms of migratory locusts is also the locust which occurs on the veldt singly and in small loose swarms during the off season of the non-migratory phase. Similar evidence has been brought forward by Johnston for the migratory locust of the Sudan, *Schistocerca gregaria*, which he shows to be a swarm phase of the non-migratory form, *Schistocerca peregrina*.

The correctness, therefore, of the **Phase Theory** of locust migration put forward by the Russian, Uvarov, can hardly be doubted. According to this view, migratory locusts are swarm phases of solitary or non-swarming forms already existing in the area subject to ravage. The reasons for this periodical appearance of the swarm phase, beyond that it depends upon some acceleration of the breeding rate, are as yet far from clear.

An interesting suggestion, put forward by Nikolski, from observation of *Locusta migratoria* in Turkestan, is that swarming takes place between separate permanent breeding grounds, or between a present-day breeding ground and an area which

was formerly a breeding ground but is now unsuitable owing to cultivation. In the latter event, since no adequate return migration occurs, owing to restriction of breeding, the numerical abundance in the true breeding area will be severely checked and the periods between the production of swarm phases will become gradually longer.

Another instance of mass migration is afforded by the case of the so-called Army Worms or Processionary Caterpillars.

The true Army Worm is a North American caterpillar of a Noctuid moth (*Cirphis unipuncta*). In ordinary years the caterpillars feed on wild, succulent grasses, and occur in low-lying situations where such food plants occur. In some years, however, caterpillars appear in enormous abundance, owing probably to some interference with the ordinary mortality factors, and they migrate in enormous numbers to the cultivated crops, especially to cereal crops.

*Thaumatopœa processionea*, the European Processionary Moth, is a moth belonging to the family Eupterotidæ, and its caterpillars march in columns, each being headed by a leader, the column becoming gradually broader behind.

**Restriction of Spread.**—The measures which can be taken by the entomologist to restrict the spread of insects are too varied and cover too wide a range to be described in detail here. It may be said, however, that restrictive measures fall roughly into the following groups :—

(1) Destruction of diseased and infected material.
(2) Collection of the insects themselves.
(3) Isolation of infested areas.
(4) Selection of pest-free seeds, plants, or stock.
(5) Rotation of crops.
(6) Disinfection of infested areas, crops, and stock.

The accidental introduction of a dangerous insect or a potential pest into a new area through the agency of man is a contingency much more important from the standpoint of the entomologist than the powers of migration which the pest may itself possess.

In its indigenous habitat, an insect may be aided by agricultural conditions to a degree sufficient to enable it to rank as a minor pest, capable of steady endemic damage, but it will rarely be able to increase its numerical abundance to such an extent as to provoke an epidemic outbreak, owing to the presence of a steady degree of mortality from various factors. In a fresh area, however, many of such mortality factors may be absent, and the insect will be capable of increase and epidemic damage to an extent not previously possible.

One of the most important ways, therefore, of limiting the spread of insect pests is by the enactment of legal measures. It must be clearly understood that the popular impression that the object of legislation against insect pests is necessarily to exterminate them is erroneous. To annihilate an insect pest is rarely possible.

Where the insect is in the "Second Class Pest" stage it may be possible to exterminate it; where it is a "First Class Pest" it is only possible to control it.

The meaning and function of legislative control of insect pests is thus :—

(*a*) To prevent the introduction and establishment of new pests from other countries.

(*b*) To prevent the further increase or spread of pests already established in the country itself.

Such legislation may be considered, therefore, as *external* and *internal* legislation. External legislation will include statutory orders against pests liable to be imported. Internal legislation will cover domestic enactments against established or newly introduced pests within the country.

Generally speaking, all countries which grow crops liable to heavy infestation by particular insect pests have either specific or general restriction orders against the importation of such pests. The importation of plants and plant products is usually only permissible when accompanied by a foreign inspection certificate, or after subjection to sterilisation at the port of entry.

An ideal system of legislative protection against the possible importation of insect pests should provide for :—

(1) Inspection of the crops of the importing country when growing. The official entomologists of the importing country should have full information on this point.

(2) Certification as to freedom from pest of all plant shipments, carried out by competent entomologists at the port of departure.

(3) Fumigation certificates issued at the port of departure.

(4) Inspection of shipments at the port of arrival.

(5) Fumigation on arrival.

(6) Quarantine of certain plants.

(7) Prohibition of entry.

In actual practice the most effective system is that of inspection on arrival, carried out by a fully competent staff in a well-organised plant inspection station; the inspection should be supplemented by certificates of inspection or fumigation issued at the port of departure and by quarantine measures.

# CHAPTER XVIII

## INSECT PESTS: The Behaviour

One of the most promising fields of entomological inquiry, from the economic standpoint, is that phase of insect physiology which deals with the reaction of the insect to the various stimuli of its environment, the likes and dislikes of the animal when subjected to sensations affecting its senses of sight, smell, touch, hearing, and so on. The general way in which an insect responds to such stimulus may be termed a **tropism,** a term borrowed from the botanist, or, better still, a **sense-reaction.** Of such tropisms, the more important are **thermotropism** (response to temperature), **phototropism** (to light), **geotropism** (to gravity), **stereotropism** or **thigmatotropism** (to contact), **rheotropism** (to currents of air or water), and **chemotropism** (to chemical substances).

Such tropisms may be positive or negative; the insect may be attracted or repelled. Many nocturnal Lepidoptera, for example, are positively photropic to a source of intense light such as an electric arc, but are negatively phototropic to daylight. Many insects are positive to the less refractive colours of the spectrum, to yellow and green. Soil insects are generally negatively photropic.

Response to light determines the choice of location of many insects, forces some to live in full light, others in darkness; some have to seek food by day, others by night.

Positive stereotropism is shown in the gregarious habits of many insects, and in the tendency of soil insects to insert themselves into crevices, into soil, or under stones, to have their bodies in contact with something solid.

Positive rheotropism is seen in the behaviour of many insects which float upon or glide upon a water surface, or in the air, with their bodies head on to the prevailing current. The Rocky Mountain Locust (*Melanoplus spretus*), for example, flies *with* the wind in a light breeze; it is negatively rheotropic; if the velocity of the wind increases, the insects act positively; they fly *against* the wind.

Application of these various tropisms to the question of

insect control has been made from time immemorial, though of course in quite empirical fashion. The majority of insect control methods depend in fact for success upon the utilisation of this principle of tropic response, and the failure in the field of methods which are of proved merit in the laboratory is often due to some tropism factor overlooked in the small scale experiments.

Upon the response of insects to temperature are based the various methods of high temperature and low temperature sterilisation. Response to temperature and humidity influences very largely the distribution and migration of insect species. Moisture, whether in soil or in stored products, may be of the utmost importance in a scheme of control. Thus, for example, air-tight storage of grain and flour against grain pests, depending as it does upon the liberation of carbon dioxide produced both by grain and insect, is most effective when the moisture content of the stored product is greater than 17 per cent. On the other hand, air-tight storage, though fatal to Acarid pests of grain or flour, is not fatal to their eggs unless the moisture content is below 11 per cent., so that freedom from Acarid infestation is best secured by keeping the moisture content of grain and flour below 11 per cent. In a climatically temperate country such as Great Britain, the usual percentage is between 12·5 and 14, so that flour intended for long storage ought to undergo some drying process.

Phototropism is the basis for many ingenious light traps, ranging from the simple lantern set in a tray of kerosene to the elaborate electric installations used in the French vineyards of Champagne for catching and destroying vine moths (*Clysia* and *Sparganothis*).

Stereotropism, again, is the basis of most traps—the belt round fruit trees, the use of flat stones and boards, for example.

Chemotropism is one of the most important tropisms of all, since upon it depends the attraction of an insect to its food medium, to its mate, and to its oviposition medium.

**Insect Food Habits.**—From what we know of the feeding habits of primitive orders of insects, for example the Orthroptera and Isoptera, it would seem that the ancestral type of insect was an indiscriminate feeder, attacking impartially any type of plant; that is to say, it was **polyphagous.**

The liability of the plant, however, to be attacked by any species of insect would become discounted by the evolution of resistance factors, such as would tend to discourage a certain number of insect species. The plant would become **resistant**

to insect attack. Such resistance in plants is well known. It may be of a general nature, a resistance to insects in general, as in the case of ivy or yew; or it may be partial, that is to say, the plant although attacked by a considerable number of insect species has established a state of equilibrium, the degree of insect attack being rarely sufficiently intense to cause serious injury. Such partial resistance is shown by most wild plants to indigenous insects. Or again, the plant or animal may be resistant to one particular kind of insect.

Thus the Northern Spy and Majetin varieties of apple are almost immune to the well-known apple pest, Woolly Aphis (*Eriosoma lanigera*). The American species of grape vine (*Euvitis*) are highly resistant to the attacks of *Phylloxera*, the vine aphis. The Chinese pear is resistant to San José Scale. Wild plants and animals are invariably less susceptible to the attacks of local insects than are domesticated or introduced varieties.

The variations which enable a plant to resist insect attack fall into two categories:—

(1) **Physico-chemical**: thickness of cuticle, of seed coat, presence of hairs, of alkaloids, essential oils, acids, gums, etc.

(2) **Physiological**: vigour, precocity, quick recovery from wounds, seasonal adaptation, absence of response to specific stimuli, etc. Such factors are often weakened by cultivation of a plant, so that the cultivated plant is usually more susceptible to insect attack than is its wild ancestor. Such a plant as the cultivated apple is notoriously susceptible to insect attack, whereas the crab apple is rarely severely injured.

It is, of course, very unlikely that any plant can develop resistance factors sufficiently powerful to keep *all* insects at bay. Even the most poisonous and noxious plants serve generally as hosts to at least one or two species of insect. The plant will have achieved a sufficient measure of success if the number of its insect guests becomes limited.

Now the effect on a polyphagous type of insect of a gradual evolution of resistance factors among its customary food plants will be a restriction of its range of food plants, for the insect will *either* have to confine itself to plants whose resistance factors are not sufficiently repellent, *or* it will have to adapt itself so completely to the resistance factors of one plant or type of plant that it becomes incapable of normal development upon plants where such factors are lacking.

It is, of course, well known that many insects with a wide range of food plants show marked avoidance of certain plants;

the field entomologist would say that they showed a *preference* for certain plants, a statement that very often conceals the real physiological significance of the habit. The San José Scale (*Aspidiotus perniciosus*), for example, a notoriously wide-spread feeder, attacks all fruit trees except chestnut, fig, cherry, and vine; it readily attacks poplar, hawthorn, beech, *Ribes*, *Salix*, lime elm, acacia, but avoids cedar, hazel, magnolia, plane, oak, and holly.

The Gipsy Moth (*Porthetria dispar*), again, is generally considered to be an indiscriminate feeder on tree foliage, but investigations would seem to indicate that even this notorious pest is restricted in habits and that its food plants may be divided into :—

(*a*) A group of plants particularly favoured, including apple, mountain ash, poplar, willow, and hazel.

(*b*) A group suitable only to older caterpillars, including chestnut, most pines and spruces.

(*c*) A group on which only a few caterpillars can develop, including varieties of elm, hickory, hornbeam, maple, pear, and cherry.

(*d*) A group *avoided* by the moth, including arbor vitæ, arrow wood, species of ash, cedar, red currant, cypress, grape vine, poison ivy, holly, sycamore, tulip tree, viburnum, walnut, honeysuckle, blackberry, raspberry, sarsaparilla, mulberry, juniper, and some varieties of pine.

The second way in which a primitively polyphagous insect may become dietetically restricted, namely, by becoming so adapted to certain resistance factors as to be unable to thrive in their absence, is exemplified by the numerous cases of species, genera, or even whole families of insects which feed only upon the members of certain food plant families, or upon plants which possess similar factors.

Thus the larvæ of the common butterflies, *Pieris brassicæ* and *Pieris rapæ*, feed for choice upon plants containing a particular glucoside, one of the mustard oils, but can be induced to feed upon leaves of other plants which have been smeared with a paste containing this substance.

The extreme type of specific food habit, restriction to one particular genus or species of food plant, may be exemplified by the Cotton Boll Weevil (*Anthonomus grandis*), which is restricted to the cotton plant; and by *Coccus fagi*, a Coccid which is never found upon any other plant but beech, and is even extremely rare on the copper variety of this plant.

The gulf between the indiscriminate type of feeder such as

the locust and such a specialised feeder as the Beech Coccus, is bridged by several stages that afford evidence as to the way one type may have evolved from the other.

Thus, for example, there is the case of the specialised feeder retaining to some extent the primitive polyphagous habit, a case illustrated by the aphid family. Most aphid species show migration from summer to winter host plants. The winter host plant is generally single or consists of a few closely related species, usually woody stemmed plants. The summer host plants may be numerous and are not necessarily related botanically, but agree in being herbaceous. The exact physiological reasons for this migration habit are not as yet clear. Possibly the onset of autumn conditions brings about the development in the herbaceous plant of physiological changes inimical or repellent to the aphis; development of a high degree of tannin, for example. In a semi-tropical climate, aphids may remain breeding and feeding on herbaceous plants all the year round, whereas in a temperate climate the same species of aphis shows migration in autumn from herbaceous to woody plants.

*Aphis prunifoliæ*, for example, in the Southern United States remains on grasses and cereals all the year round, whilst in the Northern States it spends the winter on apples.

It may be suggested that the winter host plant represents the type of plant to which the aphis is becoming restricted, and that the spring migration to herbaceous plants is a survival of the old polyphagous instinct. Now, suppose that when the aphid species migrates from summer host to winter host, some individuals to whom apparently the resistance factors of the summer plant, developing towards autumn, are not sufficiently repellent, remain behind; and likewise when the return migration occurs in the spring, individuals remain upon the winter plant. Such a habit has become established, for example, in the aphid genus *Chermes*, where we find :—

(*a*) Colonies which spend their whole existence on larch.
(*b*) Colonies which spend their whole existence on spruce.
(*c*) Forms which migrate from larch colony to spruce colony.
(*d*) Forms which migrate from spruce colony to larch colony.

That is to say, the cross migration habit has become partially suppressed in *Chermes*.

A complete or nearly complete suppression of the cross migration habit, arising after definite alternation of hosts has become established, would bring about the occurrence of distinct

**biological races** of one species ; one race confined to one type of food plant, the other confined to another type of food plant. Instances of such biological races are numerous. They may be morphologically identical, but usually slight differences in appearance between the two races arise. Thus in Canada the biological race of the Apple Maggot (*Rhagoletis pomonella*) that infests huckleberries is below the normal size ; the normal apple-bred race will not lay eggs upon the huckleberry, nor will the huckleberry race oviposit upon apple.

The test of a biological race is, of course, the possibility of changing race A into race B by subjecting A to the environmental conditions of B ; such a test established the fact that the migratory locust *Locusta migratoria* is a biological race of *Locusta danica*, despite the colour differences. Again, biological races, unless varying greatly in size, should be fertile *inter se*. Thus the two forms of louse, *Pediculus*, which attack man, although formerly looked upon as extraordinarily closely related species, *P. humanus* and *P. capitis*, were shown by Bacot to be fertile *inter se* and thus shown to be biological races, a conclusion supported by the success of Sikora in obtaining the morphological peculiarities of *P. humanus* in individuals of *P. capitis* reared on the body.

Possibly many parallel instances occur, particularly in the more recently evolved insect families, such as the Tachinidæ and among the Acalyptrate Muscidæ ; and many forms now claimed as distinct species may, in the light of fuller knowledge, prove to be biological races.

The border line between the biological race and the true specific feeder is thus often—very often—vaguely demarcated, and probably all such specific feeders, though now distinct morphologically and biologically, have passed through a biological race stage.

Of course, such biological races need not always have arisen from forms like Chermes that show cross migration between different hosts. Biological races could quite well arise from a form that, having become restricted to a few plant orders, became divided into biological groups, each adapted to a single order, as in the case of the Australian species groups of *Dacus*. Within each group, again, biological differentiation of forms adapted to particular plant species could arise.

**Chemical Control of Insects.**—The subject of chemical control is based upon the question of insect responses to stimuli, and therefore requires to be mentioned. The subject, however, is so vast that little more than the guiding principles can be

discussed here. It may be said that insecticides fall into the following groups :—

(1) **Stomach Poisons.**—These may be defined as toxic substances which can be applied to the surface of the food medium and thus introduced into the insect via the alimentary canal. They are therefore applicable only to mandibulate insects and are useless against suctorial insects. The range of substances which can be used is wide, but the majority of stomach poisons belong to one of the following groups :—

*Arsenical Compounds*, particularly the ortho-arsenates of lead, calcium, iron, copper, and sodium, and the arsenites of copper, calcium, and sodium, all of which, except the sodium compounds, are comparatively insoluble and stable in water and so are not likely to injure the plant ; the sodium salts being soluble, cannot be used upon foliage, but are valuable as a basis of preparation for the others.

*Copper Compounds*, particularly the basic sulphates, the double sulphates of copper and calcium, and the double hydrates of copper and calcium, in the form of Bordeaux mixture, obtained by precipitation of a solution of copper sulphate with an equal weight of lime.

*Alkaloids*, such as nicotine, quassiin, hellebore, and derris.

Stomach poisons are applied either as a suspension in water, or as a dust, diluted with talc, limestone, china clay, or similar substances. Stomach poisons, therefore, should be in a very fine state of division and should be used in conjunction with a slight percentage of soap, size, resin, saponin, sodium silicate, or similar substances, to induce the wash to adhere to the plant.

(2) **Contact Poisons.**—These may be defined as toxic substances which affect the insect by blocking up the spiracles, by penetrating the chitinous lining of the tracheal tubes, or by actually penetrating the external body chitin. The most successful contact poisons are substances of low volatility such as certain paraffin compounds, but polysulphides, particularly those of calcium (lime-sulphur), act as successful contact poisons owing to their strong affinity for oxygen restricting the supply for the insect and so killing it. Paraffin compounds are usually applied in the form of an emulsion in soap solution, or in colloidal aqueous solutions of iron hydroxide, basic sulphates of iron and copper, soluble silica, zinc sulphide or gelatine.

(3) **Fumigants.**—These are gaseous insecticides with which the atmosphere of an enclosed space such as a greenhouse, a tent enclosing a tree, or the hold of a ship, can be diluted or saturated.

There is no known chemical vapour which possesses the ideal combination of high toxicity to insects and low toxicity to plants or vertebrate animals, and in practice only two are known to come anywhere near the ideal; these two are *hydrocyanic acid gas* and *sulphur dioxide*, and these two gases are the two fumigants most generally employed. The former gas is used particularly for tent fumigation of fruit trees against scale insects, for greenhouses against a variety of pests, for ships, dwelling-houses, mills, warehouses, etc., where no plants are present. The latter gas is used chiefly as a fumigant for dwelling-houses and ships. It cannot be used where plants are concerned.

*Nicotine* has a certain limited use as a greenhouse fumigant in Great Britain; *formaldehyde* and *carbon bisulphide* are used occasionally for dwelling-houses, but are in greater demand as sterilisation agents; *carbon dioxide* and *carbon monoxide* are employed in certain ship fumigation processes; such substances as *chloropicrin*, *cresol*, *nitrobenzene*, *dichlorobenzene*, and the chlorine derivatives of methane, ethane, and ethylene, though full of promise, cannot be said to have got beyond the experimental stage.

(4) **Insectifuges.**—The range of substances which repel insects is wide, but their practical use is limited. A good repellent will not merely mask the attraction of a plant or animal for an insect, as do many of the deterrents recommended against mosquitoes, sheep maggot flies, onion flies, and so on, but should cause the insect intense sensory annoyance, should be pungent, or should be viscous enough to clog its spiracles or its mouth parts.

In practice this result is generally obtained by using pungent oils, but since such oils are always more or less volatile, the majority of repellents in common use are not completely successful. Repellents intended for application to animals differ somewhat from those intended to protect plants, but both kinds agree in having to be cheap, non-injurious to plant or animal, moderately volatile, and oily or pungent.

The most satisfactory repellents for use on animals are *castor oil*, *crude petroleum*, and *fish oil*, generally in the form of a soap emulsion. Certain essential oils—*aniseed*, *laurel*, *citronella*, *camphor*—are markedly repellent to insects but are evanescent. The consequent necessity for frequent reapplication somewhat debars their employment upon cattle, but is not such a drawback to their use as *culicifuges* (anti-mosquito), and they are usually so utilised.

Repellents for the protection of plants consist frequently of crude oils or coal tar products mixed with sand or chalk and applied to the base of the plant.

(5) **Dipping Fluids.**—Insecticides applied to animals for the purpose of mitigating or preventing the attacks of blood-sucking and disease-producing ectoparasites may be in the form of *hand dressings*, or *powders*, or *liquid dips*.

Hand dressings are ointments of fat or Stockholm Tar containing arsenious sulphide, free sulphur, cresols, pyridine, nicotine, mercury, and paraffin compounds. They are usually difficult to apply, necessitate shaving the hair from the affected area, and are somewhat uncertain in their action. They have been superseded almost entirely by liquid dipping preparations.

Powders are used for domesticated birds chiefly, and consist of a small percentage of cresol, sulphur or sodium fluoride diluted with plaster of Paris or slaked lime.

Dipping fluids are of three types :—

(*a*) Arsenical dips, that is to say 0·1 or 0·2 per cent. solutions of sodium arsenite ; they are used chiefly against ticks on cattle.

(*b*) Carbolic dips, usually mixtures of phenols and cresols, or of pyridine and its bases, or containing coal tar creosote.

(*c*) Sulphur dips, that is to say dipping fluids whose chief ingredient is a combination of sulphur and alkali, or sulphur and nicotine.

The last two classes of dipping fluids are extensively used against scab diseases of sheep.

It must be added in conclusion, that the old view which selected insecticides from substances known to be toxic to higher animals, and which regarded cost, killing power, and ease of manipulation as the chief qualities required in an insecticide, is gradually giving way to the more scientific conception of an insecticide as a substance not necessarily toxic to higher animals, and one in which such factors as spreading power, wetting and penetrating power, and toxic action as distinguished from mere toxic effect, are important adjuncts to the commercial qualities mentioned above.

## CHAPTER XIX

### INSECT PESTS: The Mortality Factors

THE various factors of mortality which normally prevent an insect species from increasing to an extent which might give it the status of a pest are, apart from climatic factors, those of disease, of animal parasites, and of animal predators.

The bacterial flora of insects is scarcely surpassed in richness and variety by that of vertebrate animals. The most commonly occurring pathological consequence of bacterial action upon insects, however, is septicæmia, and, in fact, the bacteria of insects never seem to show such a specificity for the host tissues as is shown by such parasites of man as *Meningococcus* and *Gonococcus*. Insects seem also to be immune to bacteria which are pathogenic to man and higher animals. Thus larvæ of the Bee Moth (*Galleria melonella*) have been shown to be completely immune to a group of organisms, including the various agents of tuberculosis, tetanus, diphtheria; to be less immune to the organisms of plague, fowl cholera, Asiatic cholera, typhus, anthrax; and to be highly susceptible to *Bacillus coli communis*, *Bacillus pyocyaneus*, *B. prodigious*, *B. subtilis*, *B. proteus*. That is to say, while susceptible to saprophytic bacteria, these insect larvæ are immune to bacteria which are highly pathogenic to the higher vertebrates. Whether this immunity is due to active phagocytosis of pathogenic bacteria, or whether it results from a physico-chemical modification of the organism brought about by the blood, and varying in intensity according to the insect individual and the character of the micro-organism, is not definitely settled.

The possibility of bacterial disease as a factor in insect control was first noted by D'Herelle in 1911, when he drew attention to a severe epidemic among the hordes of the Mexican Locust (*Schistocerca pallens*) in Yucatan which was associated with the presence, in the gut of attacked insects, of a coccobacillus, later named *Coccobacillus acridiorum*.

By passing the bacteria through the bodies of many grasshoppers in rapid succession, each insect being inoculated with a diluted extract from the gut of the preceding host, it is possible

to obtain a strain of bacillus which will kill within three hours after injection. Such a strain has been shown to be capable of inducing an artificial epidemic in another area among locusts, when cultivated and then distributed by spraying, but it must be admitted that large scale experiments in the propagation of this locust disease have given somewhat contradictory results.

Several conditions seem essential if such artificial propagation is to be successful. The locust concerned should be migratory and cannibalistic; infestation should be dense; normal food should not be excessively abundant; weather conditions should be warm and dry.

Speaking generally, experiments on species of *Schistocerca* have been very effective. Against locusts of less cannibalistic habits, such as *Pachytylus migratoroides*, the Philippine locust, *Schistocerca paranensis*, the Argentine Locust, and *Stenobothrus*, *Melanoplus*, and *Xiphidium*, of Canada, the disease seems to be less successful. Some authorities, in fact, assert that *Coccobacillus acridiorum*, or the group to which it belongs, is a normal inhabitant of the locust gut, and therefore, whilst probably pathogenic when injected into the body cavity, as in laboratory experiments, cannot be expected to be so when merely ingested.

A considerable number of fungi are known to bring about pathological conditions among insects. They may affect the insect host in various ways:—

(1) They may live on the outer body surface without either seriously injuring the underlying tissues, or injecting toxic substances into the system of the host.

(2) They may pierce the chitin and destroy the underlying tissues.

(3) They may send branching mycelia into the body, choking up the tracheæ, and causing suffocation. In the case of *Botrytis* and *Cordyceps*, the tissues become replaced by a secretion and a characteristic mummification, the so-called "Muscardine condition" of the insect, is brought about.

In the lower fungi the **Zygomycetes**, saprophytic generally upon decaying organic matter, include two groups, the *Mucorales* and the *Entomophthorales*, which are of particular entomological importance, the latter group, in fact, being almost exclusively parasitic on insects. *Empusa muscæ*, for example, belongs to this latter group, and has long been known as a parasite of various Muscid and Syrphid flies, appearing under damp autumnal conditions as a halo-like mould enveloping the fly

and ramifying throughout its tissues. Infection is probably via the alimentary canal. An interesting suggestion, albeit a disputed one, is that *Empusa muscæ* is a biological race of the saprophytic fungus, *Mucor racemosis*.

Among the higher fungi the class **Ascomycetes** includes the group *Laboulbeniales*, almost exclusively parasitic upon Coleoptera, and also many entomoparasitic representatives among the groups *Hypocreales*, *Sphæriales*, and *Erysiphales*.

Of the various Ascomycete fungi responsible for insect diseases, the best known genus is probably *Cordyceps*, better known in its conidial stage, the so-called *Isaria*. It is a fungus which occurs commonly among Lepidopterous larvæ and pupæ.

Although fungi do exercise a considerable degree of natural control over insect abundance, it cannot be said that the numerous attempts to propagate fungus epidemics artificially have obtained results which were in proportion to the amount of ingenuity expended in obtaining them.

Many such attempts have been made, notably, the use of *Sporotrichum globuliferum* in Illinois against Chinch bug during 1888-96 ; the Green Muscardine Fungus, *Metarrhizum anisopliæ*, against the Sugar Cane Frog-hopper in Trinidad ; *Aschersonia spp.* against Citrus White-fly in Florida ; *Spicaria farinosa* against Vine Moth pupæ in France ; *Botrytis bassiana* against Flea-beetles in France ; and so on.

It must be pointed out that such fungi destroy insects in large numbers only when such numbers are excessive ; it is doubtful in the extreme whether a fungus can initiate an epidemic ; it only appears in epidemic form when the insect outbreak itself is epidemic. Such insect outbreaks are frequently periodic. Thus in Florida the citrus white-fly appears in epidemic form every three years, and thus there is apparently an epidemic of fungus disease every three years. It seems impossible to create such an epidemic at any time when it does not appear naturally. Further, during an epidemic of fungus disease it is very doubtful whether the outbreak can be intensified by the spraying of spores, or by other distribution of the fungus disease. Neither does it seem possible to create an epidemic in countries where the fungus does not occur by the introduction of it, since there is generally some combination of factors which inhibits its establishment. On the whole, therefore, the use of entomogenous fungi as a method of checking insect pests is not warranted by such results as have so far been obtained.

The protozoa which may bring about disease in insects have not been studied to the same extent as have the fungi and bacteria, but the few that we know most about are members of the Sporozoa, the predominantly parasitic division of the phylum.

The earliest known protozoan disease of insects to be investigated was undoubtedly Pébrine, an epidemic disease of the Mulberry Silkworm (*Bombyx mori*) caused by the Neosporidian, *Nosema bombycis*. The recognition of the small, ovoid, shining, and motile bodies, in the tissues of infested caterpillars, as protozoa, is due to the work of Balbiani (1866), and the life-cycle was worked out by Stempel (1909), although Pasteur, in 1864, had discovered the method of infection. The latter observer showed that caterpillars may become infected in two ways :—

(1) They may ingest leaves contaminated with spore-containing fæces from infected caterpillars.

(2) The egg may contain dormant spores, so that the caterpillar is hatched in an infected condition.

The life history of *Nosema apis*, associated with a disease of bees, is similar.

It is not beyond possibility that a protozoan causative organism may yet be established for the so-called **polyhedral diseases** or **nuclear diseases** of caterpillars ; these comprise a group of infectious diseases referred to under such names as "grasserie" or "jaundice" or "wilt disease," which agree with one another in the occurrence of polyhedral bodies in the cell nuclei of the insect victims. In a caterpillar suffering from this type of disease the tissues degenerate, and a smear will show in addition to fat globules, urates, cellular débris, hairs and pigment granules, myriads of bodies varying in size between one and six microns in diameter, and in shape approximating to a polyhedron with rounded angles. They seem to be tough and elastic in nature, rather than brittle as inorganic crystals would be.

Opinions as to the significance of these bodies vary. It seems certain that they are not the actual causative organisms, but are reaction products, possibly of a nucleoprotein nature. It has been asserted that in the case of grasserie of the Nun Moth (*Liparis monacha*), the causative organism resembles the micro-organisms known as Chlamydozoa, and that the polyhedral bodies are a final stage in the life-cycle of the organism, and an infective stage, since, when a caterpillar dies and decomposes, the polyhedral bodies remain upon the leaves. On the

other hand, Gipsy Moth caterpillars fed upon leaves that have been soaked for some time in water are said to develop the symptoms of Wilt Disease.

**Parasites and Predators.**—It is not easy to draw a definite line of division between the terms **parasite** and **predator.** Both are organisms which live at the expense of another. The parasite, however, strictly speaking, obtains its nutriment from its host in an indirect manner; the predator supports itself in a cruder, more direct fashion; it is the difference between the thief and the robber.

The parasite may be a sucker of blood or of cœlomic fluid, or may absorb the fluid products of its host's digestive powers, but a true parasite does not attack the vital host tissue. It may live throughout its existence within its host, or may simply attain full size and quit the host without in either case causing fatal lesions. Death of the host, when it does occur, is due rather to exhaustion, to deficiency of those nutritive fluids abstracted from it by the parasite, or to general metabolic disturbance resulting from excessive activity of multiplication of the parasite, rather than a result of definite tissue injury. The more completely adapted the parasite is to its host, the longer will be its connection with it, and the less its liability to injure it. Tolerance of a parasite by a host, therefore, would seem to imply an interrelationship of long standing; an organism that kills its host is, comparatively speaking, a newcomer to the ranks of parasitism; it is just as much a predator as is the organism which lives by violently assaulting and devouring weaker forms of life.

To the entomologist, however, any carnivorous insect stage which limits itself to *one*, or at most two, host individuals ranks as a parasite; an organism that requires a *succession* of host individuals ranks as a predator; in the vast majority of cases, therefore, the so-called parasite of the entomologist is merely a parasite in its earliest stages only, and is afterwards a predator, since it proceeds to devour its host.

Speaking generally, the great majority of parasites of insects, using the term in its entomological sense, are themselves insects, and the great majority of predators are also insects or belong to the Vertebrata. Within the class Insecta, several families of Petiolate Hymenoptera are almost exclusively parasitic upon other insects, and are grouped together, in fact, as Hymenoptera Parasitica. Of these families, the Proctotrypidæ and Chalcididæ (Fig. 31) are large families of minute insects of various parasitic habits, but containing the majority

of egg parasites. The Ichneumonidæ and Braconidæ (Fig. 31) are larger insects, attacking particularly the larger types of insect larvæ. The Chrysididæ or Ruby Wasps frequent the

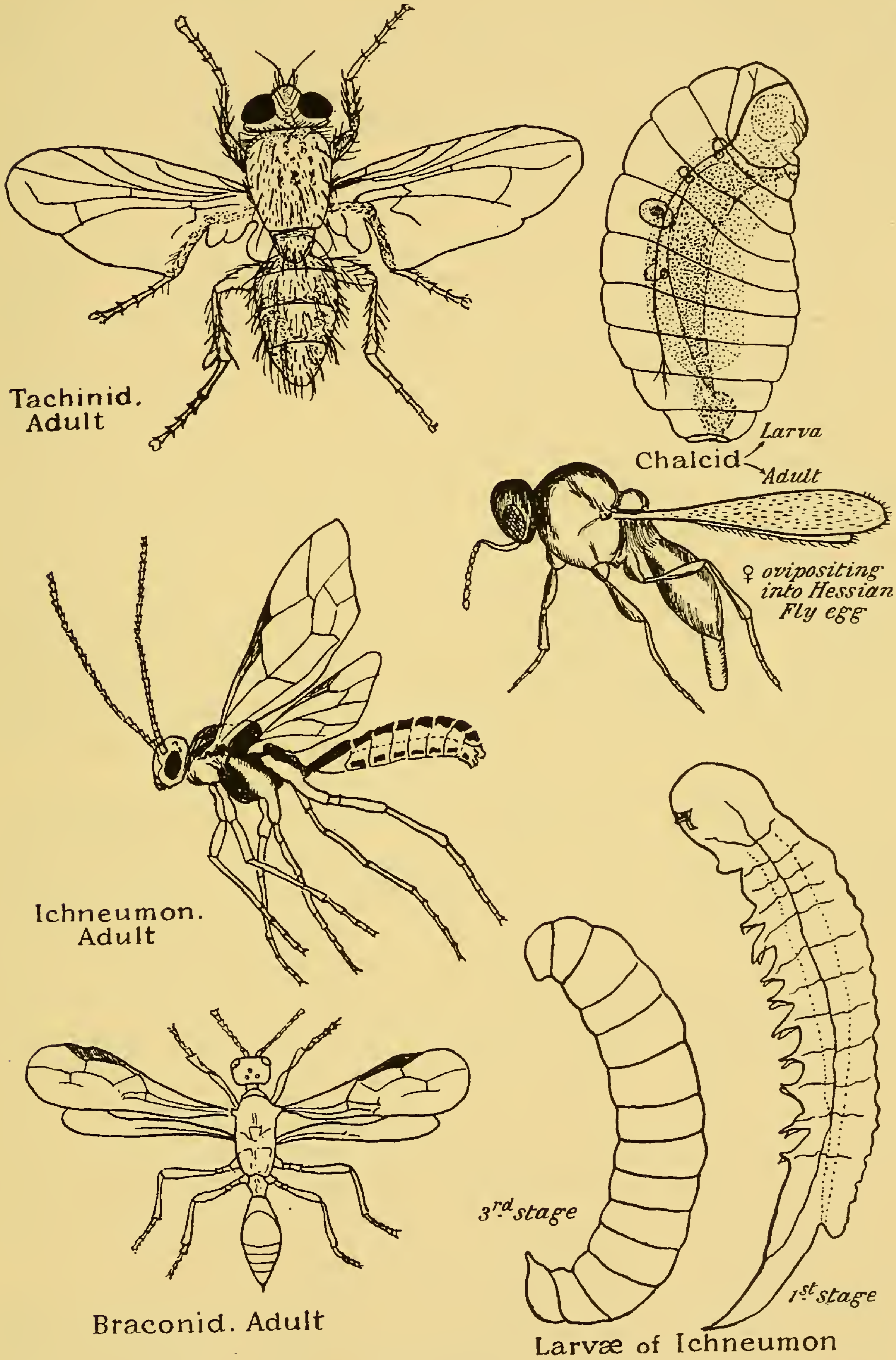



Fig. 31.—Types of Insect Parasite. (After various Authors.) (Not to scale.)

nests of Solitary Wasps, and there are parasitic bees which live at the expense of Solitary Bees and Social Bees.

Amongst Diptera the family Tachinidæ (Fig. 31) is exclusively parasitic, and chiefly so at the expense of insects. Numerous other families, such as Bombyliidæ, Nemestrinidæ, Pipunculidæ, Cyrtidæ, Conopidæ, Anthomyiidæ, Sarcophagidæ, Muscidæ, Braulidæ, are also more or less parasitic in habit.

Among Coleoptera, the Mordellidæ, Cantharidæ, and Stylopidæ are parasitic upon other insects, particularly upon solitary bees and wasps.

The chief predators upon insects are either insects themselves —particularly the Coleopterous families Carabidæ, Staphylinidæ and Coccinellidæ, and the Wasps—or they are Vertebrata. Fresh-water fishes are largely insectivorous ; Amphibia and Lacertomorphous reptiles largely so. The great majority of birds largely depend upon insects, and amongst mammals the orders of Insectivora (mole, hedgehog, shrew), Edentata (ant-eaters and armadilloes), one division of bats, and the great majority of lemurs and monkeys, depend upon a diet of insects. In Barbadoes, for example, the only species of fresh-water fish in the island is a small Cyprinodont known popularly as the "Millions" fish, technically as *Girardinus pœciloides*. This fish feeds very largely upon mosquito larvæ, and is undoubtedly of very great value as a destroyer of mosquitoes. Attempts have been made, therefore, to introduce this fish into West Africa via London, but without marked success.

**The Artificial Introduction of Parasites and Predators.**— When the native home of an imported insect, which has the status of a pest, is known, and when the insect is definitely known to be controlled in its native home by certain parasites or predators, the importation and acclimatisation of such controlling agents in the new area would seem to be a feasible policy to adopt. During recent years many such experiments have been made. Some of the experiments have met with almost spectacular success ; in others the success has been either slow in maturing or almost negligible. Among the really successful instances of parasite or predator introduction may be mentioned the introduction of the Coccinellid beetle, *Vedalia cardinalis*, already discussed previously.

The success of the Australian *Vedalia* is almost unique, although approached in efficiency and speed by the establishment of certain egg-attacking Hymenoptera in Hawaii against the Sugar Cane Leaf-hopper (*Perkinsiella saccharicida*) ; by certain parasites of the Sugar Cane Borer in the same locality ;

and by the introduction of the Chalcid parasite, *Prospaltella berlesei*, from America and Japan into Italy to control the Diaspine Scale, *Diaspis pentagona*, whose attacks on mulberry threatened the silkworm industry. Similar success may possibly result from the introduction of the Braconid, *Aphelinus mali*, into Australia and New Zealand to control the Woolly Aphis (*Eriosoma lanigera*).

On the other hand, the large scale experiments in the introduction and acclimatisation of parasites of the Gipsy and Browntail moths from Europe into Massachusetts, although undoubtedly of very great value in controlling these pests, have not met with so rapid and spectacular results as was the case with the examples quoted above.

Of course, the selection of a suitable subject for such an experiment is not so simple a matter as was formerly supposed, and the successful introduction and acclimatisation of a parasitic or predaceous insect into a new area depends upon a thorough consideration of each of a complex of factors which can only be briefly mentioned here :—

(1) The parasite should really control the pest in the native habitat. The attempt made by Riley many years ago, for example, to check the introduced Cabbage White Butterfly (*Pieris rapœ*) in America, by the introduction of the European Braconid parasite, *Apanteles glomeratus*, was doomed to failure from the outset, since the parasite is unable to control the butterfly even in its native habitat.

(2) The parasite or predator should be capable of outnumbering its host, owing to greater fecundity, or greater number of generations, or such habits as parthenogenesis or polyembryony, and so on.

(3) The parasite should be specific in its action.

(4) It should be adaptable to fresh climatic conditions and should possess the migratory habit, or at any rate should have greater powers of dispersion than its host.

(5) It should be comparatively free from enemies or from the competition of other parasites.

Its value will be entirely negatived if it is liable itself to severe parasitism.

The most suitable parasite or predator for experimental acclimatisation is, in fact, an exclusively specific parasite with few enemies; next in order of efficacy comes a polyphagous parasite; then a specific predator; and finally, a polyphagous predator.

# CHAPTER XX

## VERMIN REPRESSION

THE term vermin is one capable of various definitions according to whether the point of view adopted be that of the medical officer of health, the game warden, or the farmer.

The term, however, is one applied usually to certain mammals and birds whose activities are inimical to the interests of the farmer and stockbreeder, and it may be said to include particularly the following categories, namely :—

(*a*) Certain exclusively graminivorous birds, notably the *Fringillidœ* or finch family, the pigeons, and the parrots.

(*b*) Certain herbivorous mammals of the rodent order, notably the various species of rats and mice ; the field voles or meadow mice (*Microtus*, *Micromys*, *Apodemus*, etc.) ; the pocket gophers (*Geomys*), rabbits (*Lepus*), hamsters and cotton rats (*Cricetus*, *Sigmodon*), ground squirrels or spermophiles (*Citellus*), prairie dogs (*Cynomys*), and the lemmings (*Myodes*).

(*c*) Certain mammals and birds which are predatory upon domesticated or semi-domesticated animals, notably the wolf, coyote, dingo, fox, house cat, weasel, stoat, polecat, and to a lesser extent the larger cats ; among birds, certain hawks and owls such as Cooper's Hawk, the Sharp-shinned Hawk, and the Eagle Owl, all of North America, and the Sparrow Hawk and Little Owl of Europe ; the Kea Parrot of New Zealand.

It must be noted in fairness that animals and birds of this latter category are often seriously destructive only when transferred to a new environment, or when in excessive numbers, or through scarcity of their normal food.

The great horned owl and the coyote are cases in point. Where rabbits or field rodents are numerous, the owl and the coyote are very rarely tempted to attack domesticated stock ; coyotes are known to feed very largely at times on large insects such as grasshoppers and crickets. Even the much maligned fox relies very largely upon field mice, rabbits, ground squirrels, and insects ; in Algeria it has been found difficult to establish the large predatory beetle *Calosoma*, imported from Europe, owing to foxes.

**Injurious Rodents.**—The most injurious rodents belong to

the genus *Mus*, and comprise some 300 species, seven-eighths of which are classed as rats, the remainder as mice ; the difference is chiefly one of size, those with feet longer than 30 mm. being distinguished as rats. Of these species, three in particular, owing to cosmopolitan distribution, adaptability to various conditions, and omnivorous habits, are world pests. These three species are :—

**Mus rattus,** the Black Rat or Ship Rat, with several subspecies, in particular *Mus rattus alexandrinus* (the roof or tree rat of the Mediterranean area) and *Mus rattus concolor* of Java and Burma. It is pre-eminently the common house rat of tropical Asia, and the most important agent in the dissemination of bubonic plague. Although occurring in Europe in mediæval times, and probably concerned in the plague outbreaks of Europe in those times, it has now been driven to the seaports, largely through competition with the Grey Rat. Outbreaks of plague, therefore, although always liable to be epidemic in Asiatic cities such as Bombay and Hong-Kong, only occur in Europe or America or Australia, rarely, in minor form, in such ports as Sydney, Adelaide, San Francisco, Liverpool, and so on, particularly in the Asiatic quarter. It is the predominant rat of Asia, owing possibly to the infrequency of stone houses, sewers, and cellars, and owing to its superior climbing powers is more commonly found in ships than is the Grey Rat. The typical colour is not the bluish-black of European varieties, but a soft reddish-brown with belly white or pale yellow. It is a slender rat, with large ears, long tail, and prominent eyes (Fig. 32).

**Mus norvegicus (decumanus)**, the Brown, Grey, or Norwegian Rat, is a larger species than the preceding one. It has a reddish-brown or grey back and a silvery-grey belly, and has the tail shorter than the rest of the body. A black variety occurs, often termed the Irish rat, which is said to be on the increase.

The original home of *Mus norvegicus* was probably China, and *Mus humiliatus* of that country may represent the ancestral form, although a wild form, *Mus norvegicus primarius*, has been reported from the region west of Lake Baikal. It was probably introduced into Great Britain in ships from the Baltic about 1728, into America about 1775, and in both countries it rapidly ousted the Black Rat. It is essentially a burrower, a frequenter of drains and sewers, and can establish itself in stone or brick-built erections unfavourable to *Mus rattus*. Unlike the latter, however, it requires to be near fresh water, being a great drinker and a ready swimmer and diver.

**Mus musculus,** the House Mouse, in all probability came from Asia also, but its establishment in Europe must date from a long way back, certainly not later than the Neolithic period. It is a miniature replica, in appearance and habits, of the Black Rat. Several local races exist, particularly in isolated island communities such as St Kilda and the Faroe Islands.

All these forms of *Mus* are very prolific and attain sexual maturity early, at four months at the latest. They breed throughout nine months of the year, and as gestation only lasts three weeks, some five or six litters may be produced annually, a litter averaging eight to ten in number. It must be remembered, however, that as wild rats will rarely breed in captivity, such figures are based upon observation of the domesticated white rat, and are probably far too low for the wild forms. Litters of twenty-one and twenty-two young brown rats have been recorded.

The rat is omnivorous, and will eat almost everything that is edible, will gnaw wood, ivory, leather, lead piping; will destroy textile stuffs, paper, books; and will attack chickens, rabbits, young lambs and pigs, even horses' hoofs. They have, however, several preferences, and *cultivated cereals* are particularly favoured. They will attack newly sown seed, young shoots, or the mature grain. Where maize is grown they will even climb the stalk and strip the cobs clean. Malt is proverbially a favourite food.

Of little less importance than the rats and mice of habitations are the true field rats and prairie mice, belonging also to the Murid sub-family **Murinæ**; the voles or meadow mice and lemmings belonging to the sub-family **Microtinæ,** and distinguished from the *Murinæ* by their heavier build and stumpy tails; the family **Geomyidæ** or pocket gophers, ground tunnelling forms peculiar to North America and causing great damage there to forage crops; the family **Sciuridæ,** including tree squirrels, ground squirrels or spermophiles, and prairie dogs; the **Leporidæ,** including the rabbit, now such a plague in Australia.

Field rats include the **Bandicoot Rats** (*Nesokia*) and the **Mole Rats** of tropical countries; in temperate latitudes, however, field-dwelling *Murinæ* are not numerous, their place being taken to a large extent by voles and lemmings, gophers and ground squirrels.

In Great Britain there are three species of field mouse, namely, the prehensile tailed **Harvest Mouse** (*Micromys minutus*) whose spherical nest, large as an orange, is suspended on a cereal stalk some distance from the ground, the long-

tailed **Field Mouse** (*Apodemus sylvaticus*), and **De Winton's Field Mouse** (*Apodemus flavicollis wintoni*).

The voles, meadow mice, and lemmings belong to a subfamily of Muridæ known as the *Microtinæ*, a group of small animals distinguishable from true mice by the heavier build, blunt muzzle, short ears and tails. They are, in general, feeders upon coarse herbage and grasses.

In Great Britain five species of vole occur : the **Bank Vole** (*Evotomys glareolus*), the **Short-tailed Field Vole** (*Microtus hirtus*), and the **Highland Field Vole** (*Microtus agrestis neglectus*) are all forms about the size of a mouse, and, with the exception of the last-named species, are distributed throughout the country ; the **Water Voles** (*Arvicola amphibius* and *Arvicola amphibius reta*) are larger, rat-like forms, adapted to aquatic life, although as the feet are not webbed, such adaptation would seem to be recent.

In North America the economically important forms belong to the genus *Microtus*, and are usually termed **Meadow Mice,** the commonest species, *Microtus pennsylvanicus*, occurring in at least twenty-five States from Maine to the Dakotas. In North America occurs the aquatic **Musk-rat** belonging to the genus *Fiber*.

The habits of *Microtinæ* differ greatly ; there are forest forms and prairie forms, burrowing forms and surface forms, dry ground forms and aquatic forms. The nests are compact, spherical bundles of dried grasses, placed in depressions in the ground, in shallow burrows or on grass stems above the ground. From the nest, trails of great length lead to neighbouring feeding grounds. The trails of some species are below ground, and short tunnels are common with most species. Surface nests are usually for shelter only ; the young of most kinds are born in underground nests. The animals are enormously prolific, four to six litters of eight to twelve young within a year being usual.

The **Lemming** (*Myodes*) is distributed throughout Northern Europe, with the exception of Great Britain, usually living upon the slopes of mountains above the pine belt. It is a thick-set, clumsy rodent about the size of a small rat, yellowish-brown in colour, with blunt muzzle, short tail, and short ears. It is remarkable for its periodic migrations, during which vast hordes, numbering millions of individuals, move westwards, surmounting all obstacles, until in Scandinavian countries they reach the sea, into which they are even said to continue their movement and so to perish.

The **Hamsters** (*Cricetinæ*) are somewhat primitive forms

which include the Old World genus *Cricetus* and the **Cotton Rats** (*Sigmodon*) of North and Central America.

The common hamster (*Cricetus frumentarius*) is abundant in some districts of Germany, and is a glossy-coated animal about a foot long, possessing cheek pouches. It constructs two kinds of burrow, a summer one for a nursery and a winter one for food storage and hibernation.

Hamsters are very destructive to crops, and hoard up large quantities of grain. As much as 120 lbs. weight of seeds (wheat, rye, beans, etc.) have been taken from a single burrow.

The family *Geomyidæ* comprise the so-called **Pocket Gophers,** a family of rodents restricted to North and Central America, and in North America distributed chiefly west of the Mississippi basin.

In some districts in this area, pocket gophers are probably of greater economic importance than all the other species of rodents combined. The damage done by pocket gophers in the United States was estimated so far back as 1908 to exceed 12,000,000 dollars (£2,500,000) per year, and the statement was probably grossly underestimated. It is no exaggeration to state that on many farms of Western North America, 10-30 per cent. of the crop is lost annually through the activities of pocket gophers, aided to a lesser extent by prairie dogs, ground squirrels, and rabbits. The animal is a thick-set, short-legged rodent, a little smaller than the house rat, provided with fur-lined cheek pouches which open outside the mouth (Fig. 32).

It is entirely fossorial, living in underground tunnels, about two feet below the ground surface, which form a complicated labyrinth. At intervals of a few feet, shafts run up to the surface and are marked by a mound of earth, the so-called gopher hill, about a foot high and several feet in width.

The food consists of roots of plants which are attacked from below, and without the animal emerging from its burrow. The gopher is particularly destructive to alfalfa, grazing land, hay meadows, and root crops. Alfalfa may be entirely ruined by the cutting of the main branches of the root system.

In irrigated districts much damage may be done to the banks of irrigation ditches by leakage of water from them through gopher burrows. Bell quotes the example of an irrigation canal in Idaho, whose bank broke down through the weakening caused by gopher burrows ; the break cost 5,000 dollars (£1,000) to mend, and before repairs could be completed the enforced drought caused a loss of 25 per cent. of the hay crop over 30,000 acres of country.

The family *Sciuridæ* includes not only the **Tree Squirrels,** but

certain North American terrestrial burrowing forms variously known as **Prairie Dogs, Spermophiles, Woodchucks,** and classified as a separate sub-family *Marmotinæ.* They are gregarious


Fig. 32.—The Grey Rat, Black Rat, and Pocket Gopher.

burrowers, inhabiting a " town " or warren of burrows connected by a labyrinth of tunnels; they are diurnal feeders and are said to hibernate through the winter and so do not need to store up food for the winter.

The **economic aspect** of the rodent question may be discussed under three headings :—

(1) Habitual, steady damage to food-stuffs and property. Many statements have been made concerning the total annual damage to property and materials in various countries caused by rodents, but accurate information is difficult to come by and the figures are sheer guesswork. In addition to the amount of food actually eaten, there is the almost incalculable loss from wastage and spoliation, and the damage caused is so gradual and unobtrusive, such a chronic tax on food-stuffs, that statistics can rarely be made concerning it.

(2) Damage caused by rodent plagues.

The habit of assembling in large numbers and migrating has been observed frequently among rodents. Such migrations are often only seasonal, brought about by the presence in some area of a large accumulation of favourite food. In Great Britain, for example, there is a large influx of rats into the East Coast fishing ports during the herring season, and a corresponding return to inland farms when the season closes. In South Australia and Victoria the large accumulation during 1916 and 1917 of wheat sold to the British Government on the wharves awaiting shipment attracted billions of mice, and damage to the extent of £1,000,000 was done. In one wheatyard 10,000 were killed in one afternoon. Great numbers died from a disease resembling syphilis.

Such mouse plagues or rat plagues are, however, more frequently due to an abnormal increase in numbers, following a succession of mild winters and abundant summer harvests. Inadequacy of food forces myriads of rodents to spread over less populated areas. Such migration is particularly characteristic of voles and lemmings. Such a plague of meadow mice in 1907-08 devastated four-fifths of the cultivated areas of Nevada, Utah, and north-east California. One-third of the alfalfa crop was ruined, three-quarters of the potatoes, and an enormous number of young shade trees killed.

Such plagues resemble one another in being preceded by one or two favourable years during which mice are abundant, and in rarely lasting beyond one year. The importance of the natural checks afforded by owls, hawks, weasels, stoats, crows, rooks, gulls, etc., is enormous. The field mouse and meadow mouse are sufficiently prolific to produce a plague every four or five years in the absence of such enemies, and the general tendency of gamekeepers and agriculturists to destroy such natural enemies is to be deplored. The great field vole plague

that ravaged the South of Scotland in 1892 was undoubtedly the result of years of systematic persecution of owls and hawks.

(3) Conveyance of disease.

The connection between rats and bubonic plague has already been discussed in this and previous chapters, and the relation that exists between rats and trichinellid worms has also been referred to. In addition, rats are suspected of carrying the virus of horse influenza, and Japanese observers claim that *Spirochæta icterhæmorrhagiæ*, the causative organism of an infectious jaundice in man known as Weil's Disease, is transmitted from rat to man by urine contamination of food.

**Methods of Destruction.**—The destruction of injurious mammals and birds can be carried out by poisoning, or by trapping or hunting.

**Poisoning** is the cheapest and most convenient method of dealing with burrowing mammals or with the larger carnivora, although a method which requires great care in poultry-raising districts.

Strychnine-coated wheat or barley is undoubtedly the most satisfactory way of dealing with sparrows, with ground squirrels, meadow mice, rats, rabbits, and so forth, especially if used in winter, but strychnine is less successful against the cunning of large carnivora. The substance used is usually strychnine sulphate, which is soluble in boiling water. The intense bitterness of this salt may be neutralised by mixture with an equal weight of sugar or orange juice, or better still, of saccharine. The bait used will vary with the habits of the pest whose destruction is aimed at, but the following may be used: cereal or leguminous seeds, bran, alfalfa, cubes of potato, sweet potato, carrot, beet, parsnip. The bait should be soaked overnight in a syrup made up, for example, of one ounce of strychnine, one ounce of sugar, one pint of boiling water, and a few drops of aniseed oil.

With burrowing animals the bait is placed in the mouth of the burrows. With other rodents it is best placed under a board resting on thin cross-pieces, so as to exclude birds.

Other poisons used are arsenic, potassium cyanide, barium carbonate, squills, phosphorus. All have their advantages and their drawbacks. Barium carbonate is much used against rats, owing to its absence of odour and taste, and its low toxicity towards larger animals. It is mixed with four parts of flour into a dough, flavoured with aniseed, and disposed in lumps about the size of a hazel nut. It is, however, like the more dangerous phosphorus, slow in action.

**Fumigation** with poison gas has proved successful against ground squirrels, gophers, and prairie dogs. The favourite substance employed is the volatile liquid, carbon bisulphide. It should preferably be pumped into burrows by means of a "destructor," a sort of pump, but may be simply placed in the mouths of burrows on a sponge or handful of rags, and the external entrance blocked. Coarsely powdered calcium cyanide is also much used. Fumigation is useless where burrows are long and deep, or labyrinthine. It is useless against rats.

Fumigation of ships is, however, a much practised and successful method against rats. Usually the Clayton process is used, a method of wafting sulphur dioxide into the space to be disinfected. This gas kills ship insects—cockroaches, fleas, bugs, mosquitoes—very readily, but as it does not penetrate into the deeper recesses of the hold, owing to the mechanical difficulties offered by tightly packed cargo, and owing to the absorption of much of the gas by such cargoes as cotton and jute, a considerable number of rats are liable to escape. A mixture of carbon dioxide and carbon monoxide, although without toxic action on insects, is lethal to rats, and at many American ports this mixture is introduced into ships by a method invented by Dr Harker, of the University of Sydney. The Harker apparatus can deliver 180,000 cub. ft. of waste furnace gases per hour, chiefly carbon dioxide, carbon monoxide, and about 10 per cent. of oxygen. It has been adopted in many shipping ports primarily as a fire extinguisher. In other ports opinion favours the use of hydrocyanic acid gas as a ship fumigant.

**Trapping** is a very safe method, can be used at any time, and is very effective in the hands of a skilled man. Traps are especially adapted to buildings, to pastures where livestock are running, to gardens, orchards, and to banks of ditches and streams. Against wolves, foxes, dingoes, coyotes, it is one of the few successful methods. The notorious "Custer Wolf" of South Dakota, U.S.A., which destroyed thousands of pounds worth of cattle, was taken eventually in a trap after all other methods failed. It is interesting to note in this connection that in the Western United States no fewer than 109,346 coyotes, 15,374 lynxes, and 2,936 wolves were killed by shooting or trapping during five years, 1st July 1915 to 30th June 1920, apart from the very large numbers poisoned. This work was carried out by the Bureau of Biological Survey of the U.S. Department of Agriculture.

## CHAPTER XXI

## BIRD ENCOURAGEMENT

BIRDS may be divided, according to food habit, into three groups :—

(1) Birds that are **insectivorous** or **carnivorous**, a group including particularly aquatic and marine birds, falcons and hawks, owls, plovers, cuckoos, swifts, woodpeckers, and such families of Passerine birds as the fly-catchers, swallows, *Turdidœ* (thrush, blackbird, robin), and the *Paridœ* (tits), although the last two families are to some extent graminivorous.

(2) Birds that are **graminivorous**, relying almost exclusively upon a diet of seeds and fruits ; this group includes particularly the pigeons, parrots, and finches (sparrow, chaffinch, etc.).

(3) Birds that are **omnivorous**, accepting seeds or insects with equal readiness ; a group of birds which includes the Galliformes or Game birds (pheasant, quail, bobwhite, grouse, partridge, fowl), the larks, the starlings, and the *Corvidœ* (rook, crow, magpie, jay).

At first glance, birds in the first group would appear to be potentially beneficial to the agriculturist. Birds in the second group, if sufficiently numerous or gregarious in habit, would appear to be potentially injurious ; birds in the third group might be either injurious or beneficial, according to the nature of the crops grown in the locality or the season of the year.

A superficial knowledge of the food habits of any bird or class of bird is, however, not sufficient to warrant any definite statement concerning the bird's economic status. An insect-eating bird, for example, cannot discriminate between the injurious and the beneficial insect, so that of the six and a half million insects destroyed by a tit in one year, a large number has to be reckoned against the bird. Of the animal food taken by the European rook, probably quite one-third must be reckoned against the bird. As a matter of fact, the importance of birds as factors in the control of insects has probably been exaggerated in recent years. It is indisputable that very many insects are eaten by birds, but there is very little evidence of any epidemic of insect attack having been checked by birds.

On the other hand, there is abundant evidence as to the value of predatory insects in such epidemics. It cannot be said that countries such as France or Italy, where small birds are ruthlessly hunted, suffer more severely from insect attack on crops than do countries such as Great Britain or the United States, where public opinion is opposed to the unnecessary destruction of birds. It must be added that carnivorous insects are often more conspicuous in size or habit than herbivorous forms, and thus may suffer more severely from the attack of birds than do the latter forms.

Again, the activities of a carnivorous bird may be in some respects detrimental to the interests of the agriculturist. The European sparrow-hawk preys upon the small Passerine birds, particularly the hedge-loving insectivorous forms; a similar habit is shown by the North American sharp-shinned hawk; Cooper's hawk, of the same region, attacks poultry; and the similarly distributed goshawk and great horned owl kill large numbers of game birds.

Birds whose habits are graminivorous may not be wholly injurious to the farmer. The English chaffinch has been proved to take large quantities of such troublesome weed seeds as chickweed, hawkweed, dock, and knotgrass, the percentage of weed seeds in the crop being sometimes as high as 95 per cent. In the United States the score or more of native species of sparrow are most efficient weed consumers, and even such notorious grain eaters as the English sparrow, bobolink, dove, and blackbird (*Agelaus*, *Ouiscalus*) will at times consume quantities of weed seeds.

The economic position of such weed-consuming birds, however, depends upon whether weed seeds can pass through the alimentary canal of the bird intact and capable of germination, for in such an event the diminution of weeds in a particular area will be counterbalanced by a wide distribution of such weeds elsewhere. Unfortunately, the evidence bearing upon this question is somewhat contradictory. It would appear that, generally speaking, birds which possess muscular gizzards and are accustomed to feeding upon hard seeds crush the seed coats so effectively as to prohibit any possibility of germination; such is the case with the turkey, fowl, pigeon, duck, crossbill, siskin, tits, serin-finch. On the other hand, in the case of birds whose diet is chiefly insects, such birds, for example, as the thrush, robin, blackbird, seeds are readily excreted and a high percentage of such seeds are able to germinate.

Another factor that must be taken into consideration in

estimating the economic status of a species of birds, is the nature of the food taken by the nestlings, for not only is the

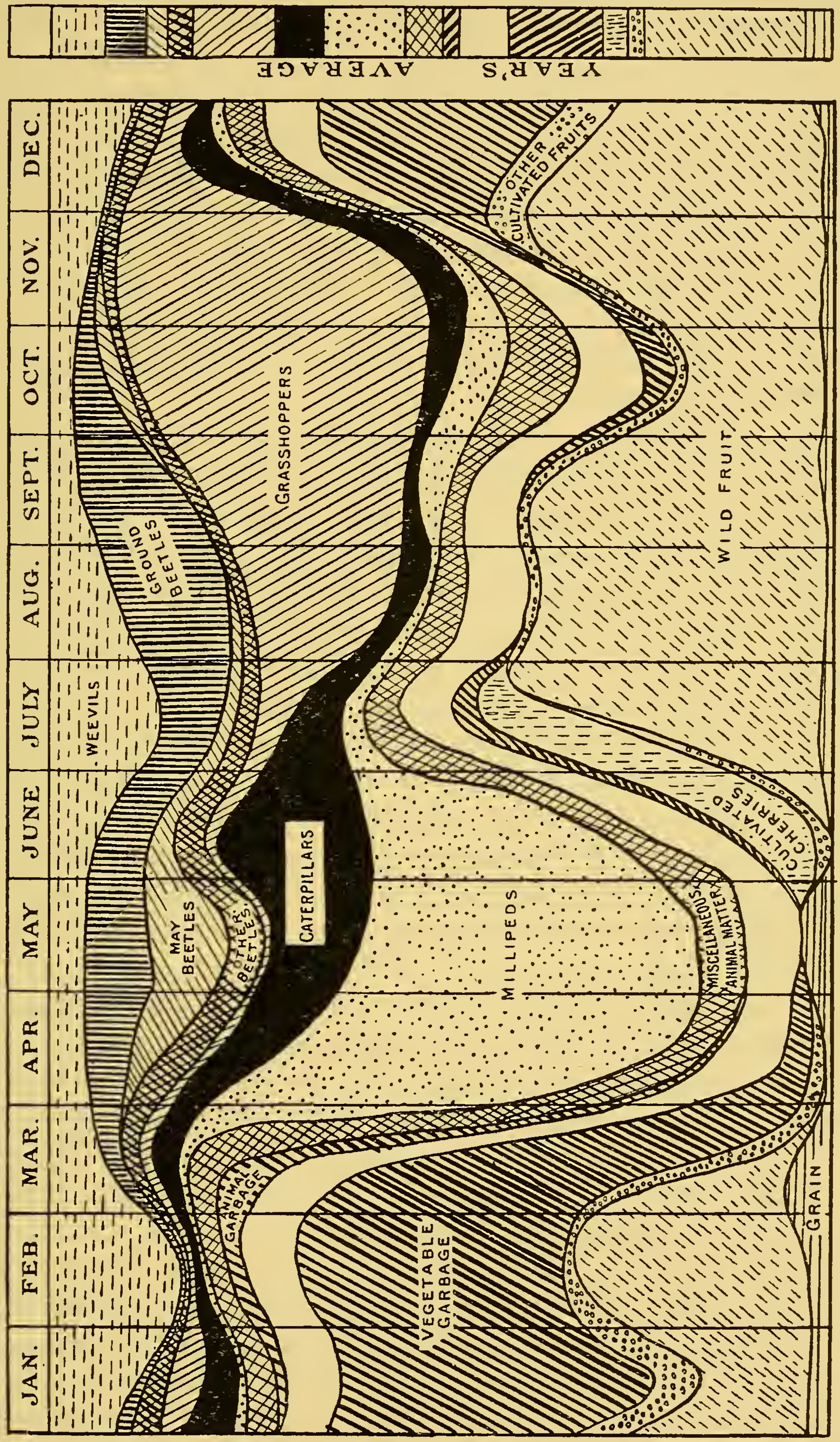



FIG. 33.—The Diet of the Starling in North America. (After B. Kalmbach and Gabrielson. Bul. 868, U.S. Dept. Agric.)

quantity of food per day consumed by a nestling relatively enormous, but almost all birds, except doves and pigeons, feed

their young upon an animal diet, irrespective of the diet of the adult. As nestlings increase in weight from one-fifth to one-third daily, and at certain stages of growth require daily more than their weight of food, it is essential that the food should have a high nutritive value and should be easy of digestion. Spiders, caterpillars, and grasshoppers are therefore a favourite nestling food with many species of Passerine birds. Birds such as finches that are largely vegetarian, mingle fruit or grain in constantly increasing quantities with the insects fed to their young, though insects predominate in the diet until maturity is nearly reached. These birds, however, generally make use of hard insects—carabid beetles, weevils, and so on ; but sparrow nestlings will consume a comparatively large number of caterpillars.

Sweeping statements concerning the utility or the uselessness of this or that species of bird are based too often upon the most superficial field observations, and are to be distrusted. Such statements are in fact valueless and even mischievous, unless based upon stomach examinations of *large numbers* of individuals from *widely distributed* localities throughout *all* months of the year for several years. The economic position of a species of bird may depend to a large extent upon its abundance, upon the availability of food other than its favourite food, upon the nature and times of crops in the locality. Evidence from isolated observations, from stomach examination of only a few individuals, shot perhaps in restricted localities or at some definite time of the year, is worse than useless. Particularly is this the case with birds such as rooks or starlings, whose diet is a mixed one.

Further, the exact locality of each specimen should be known, the character of the land, the crops grown there, whether the district is wooded, whether broken up by hedges, ditches, or walls, what the bird was doing when shot, whether it was in a flock, what the weather was like, and so on. Such evidence must be supplemented by well authenticated field observations and by stomach examination of nestlings.

Investigations on such lines have been carried out in North America and in Europe by several observers, but considerations of space will not permit of any detailed account of the mass of facts thus available regarding the dietary of many common birds.

It may be affirmed, as regards Europe, that most authorities are agreed that the house sparrow, tree sparrow, and wood pigeon are inimical to cereal production. That the rook, bullfinch, lark, blackbird, and missel thrush are injurious if

in excessive numbers; the starling, chaffinch, and sea-gull beneficial on the whole; cuckoos, swifts, lapwings, woodpeckers, and the majority of Passerine birds, particularly *Paridæ* (tits), *Turdidæ* (thrushes), *Muscicapidæ* (fly-catchers), and *Hirundinidæ* (swallows), are of the utmost value.

In North America opinion favours the protection of the following birds: the blue jay, one of the very few birds fond of hairy caterpillars such as tent caterpillars (*Malacosoma sp.*); the crow, which controls June beetles (*Lachnosterna*), white grubs, and young field mice; the sparrow-hawk (*Falco sparverius*), which feeds chiefly on grasshoppers and crickets; robins, thrushes, and cat-birds, the last of which will feed its young on cabbage worms; the cuckoo, which also eats hairy caterpillars; woodpeckers, which destroy ants, borers, and insect eggs in winter; the flicker, which eats ants in large numbers; orioles, which are particularly fond of aphides; and quails, which are in special need of protection owing to their destruction for food, and which devour the Colorado Potato Beetle (*Leptinotarsa decemlineata*), the Striped Squash Beetle (*Diabrotica vittata*), the Boll Weevil (*Anthonomus grandis*), the Chinch Bug (*Blissus leucopterus*), grasshoppers, cutworms, and many other injurious insects. As regards the horned lark, although the belief of farmers that the bird eats newly sown wheat appears to be supported by stomach examinations, the percentage of wheat eaten is small and is compensated for by the large percentage of insect food, so that on the whole the bird may be regarded as beneficial.

Opinion is unanimous in both Europe and North America as to the economic status of the English sparrow (*Passer domesticus*) and its numerous sub-species and races. Careful examination of the crop contents of sparrows in both Europe and the United States has established the fact that up to 75 per cent. of the food may be cereal in nature. The nestlings, it is true, are fed chiefly on caterpillars, but the nestling season is short. The sparrow's ability to rear young under urban conditions, where it is protected to a large extent from predatory birds and mammals, its prolificacy, its boldness and hardiness, and its gregarious habits, are all factors which produce the enormous flocks of sparrows which issue from the urban centres to attack adjoining cereal-growing districts. Even in a town it is not wholly desirable, since its pugnacious habits discourage many more desirable types of Passerine birds which tolerate urban conditions. In the eastern United States the sparrow, since its introduction from Europe, has increased to such an

extent that its numbers constitute a veritable scourge to agricultural districts.

**Bird Protection.**—Legislative measures for the protection of bird life may be classed as State or Provincial, Federal or National, and International Legislation.

Speaking generally, a wild bird protection scheme of legislation should be based upon the following principles :—

(1) It should be in keeping with present-day notions of bird protection.

(2) It should give some general protection to all birds by prohibiting certain methods of destruction and capture involving obvious cruelty.

(3) It should not otherwise protect a bird species which careful investigation has shown to be harmful. In this respect, since the economic status of a species may vary according to locality, the measure should permit of modification according to local conditions.

(4) Remaining species of birds should be divided into three categories, according to their economic status, their æsthetic value, their degree of abundance, the categories being as follows :—

(*a*) Species which should receive absolute protection at all times for adult, nestling, egg, and nest.

(*b*) Species which should receive absolute protection for adult, nestling, egg, and nest only during a specified portion of the year, to be denoted the *closed season.*

(*c*) Species which should receive absolute protection for adults, but not for nestlings, eggs, or nest during the closed season.

(5) The onus of responsibility for evading the protective measures should rest with the person in possession of illegally taken birds, eggs, or nests. In this respect taxidermists should be compelled to keep a register concerning the nature and origin of specimens received by them.

In most civilised countries to-day there exists some form of bird protection legislation incorporating some or all of the above principles. It is true that, even in contiguous States, the results accruing from bird protection measures may differ considerably, according to the interpretation placed upon the question as to what decides the economic or æsthetic value of a bird species to the community, and according to the stringency with which penalties for evasion are applied. Any legislative protection of wild life is of doubtful value unless accompanied by a system of educational propaganda to enlighten the community as to the necessity for such measures.

In North America, State or Provincial Laws concerning bird protection vary in detail between one State and another, but they are usually based on the assumption that all game and wild birds are the property of the State and may only be killed as the State Government permits. Landowners have no privileged position in this respect.

This is in striking contrast to the system in European countries, where Wild Bird Protection Acts are hampered in their application by undue consideration for the rights of landowners.

**International Legislation** concerns, or should concern, itself with three outstanding problems in bird protection, namely: (*a*) the case of birds which migrate from one country to another; (*b*) the question of plumage hunting and marketing; and (*c*) the question of pollution of extra-territorial waters by refuse oil from ships.

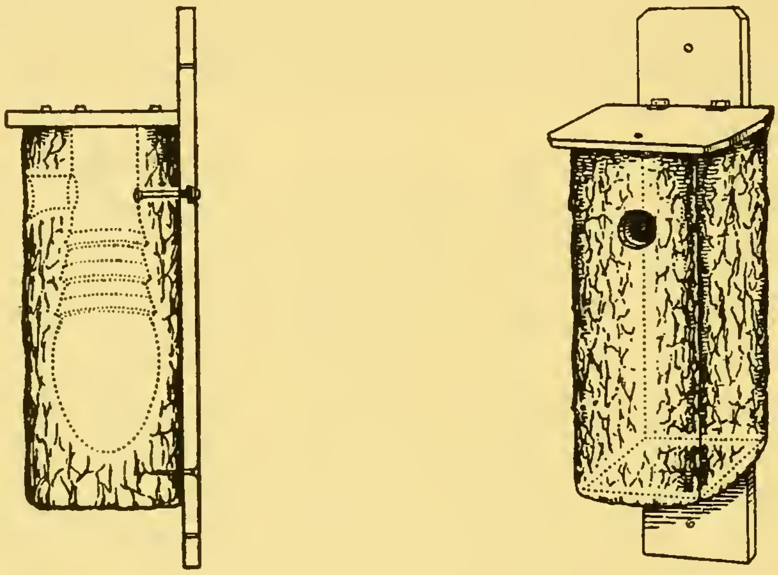
In North America the problem of the migratory bird has been dealt with by the Migratory Bird Convention Act of 1916 between Canada and the United States. This international measure is one of the most important and far-reaching bird protection enactments ever made. It affects more than one thousand species and sub-species of birds from the Gulf of Mexico to the North Pole. The important articles in the Convention are those which provide for a close season of migratory game birds from 10th March to 1st September with certain limitations, and an absolute protection throughout the whole year for migratory insectivorous birds. The open season for wild fowl is limited to three and a half months between 1st September and 10th March.

Some years ago, efforts to secure international protection of birds in Europe broke down owing to the diversity of interests and opinions, and the apathy of the governments concerned. Such difficulties are less marked in North America, and there exists there an increasing sentiment in favour of wild life preservation. It may be added that within the confines of the United States themselves, migratory birds are protected by the so-called M'Lean Federal Migratory Bird Law.

Attempts to secure international agreement concerning the prohibition of the trade in the plumage of rare birds have not as yet been successful.

In the United States, owing largely to the efforts of the New York Zoological Society and the National Association of Audubon Societies, the importation or sale of the plumage of wild birds, either raw or manufactured, except for educational

or scientific purposes, has been absolutely forbidden since 1913. Since 1915 the Dutch Colonial Government has prohibited the destruction and exportation from Dutch colonies of all birds except the lesser bird of paradise (*Paradisea minor*), the twelve wired bird of paradise (*Seleucides nigricans*), and the rifle bird (*Ptilornis magnificus*). The importance of this measure may be judged by the fact that the Dutch East Indies were the chief centres from which birds of paradise, crown pigeons, and other tropical birds were exported to Europe; the Papuan hunters of Dutch New Guinea employed by the Chinese traders of Ternate used to secure an average number of 200,000 skins per year. Of the eighty-one or eighty-two species of paradise birds,



"Berlepsch" "Thirlmere"

Fig. 34.—Types of Nesting Box.

about twenty are now nearly extinct on the smaller islands owing to these depredations.

In Great Britain, despite considerable opposition not only from the feather trade but from certain naturalists, the Importation of Plumage Act was passed in 1921 and, with certain scheduled exceptions, the plumage and skins of wild birds are not allowed to enter the country. Germany and Austria may follow these examples. France and Belgium are too greatly under the influence of the plumasserie or feather trade to be in a position to enact similar measures.

The Himalayan species of pheasant, however, is still accessible to the feather trade. The laws of British India forbid the exportation of skins or plumage taken in British India, but Nepal, an independent State, can still export thousands of pheasant skins to Europe, and the Nepalese have

almost exterminated the Minal and the Tragopan and possibly others of those gorgeous pheasant species.

One common objection raised by opponents of these legislative measures against plumage importation is that it will tend to discourage the domestication of birds of plumage value. The usual retort has been that by the time experiments could be made and bird farms established on a scale sufficient to supply the feather markets, all the wild birds would be exterminated.

Actually in India the successful raising of egrets for plumes has been carried on for some years in the province of Sind,

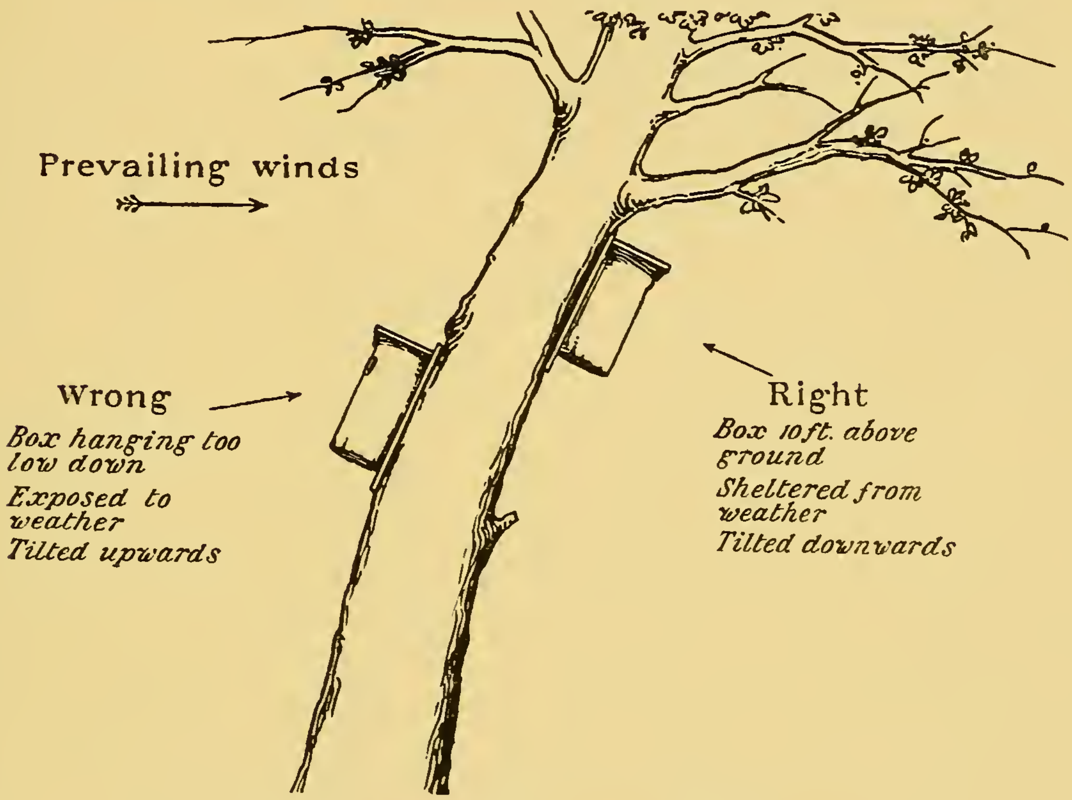



FIG. 35.—Method of Hanging Bird Boxes.

the birds being kept in mat-enclosed pens about eight feet square and fed on small fish. The birds become tame and can be readily handled, and the plumes plucked without injury to the bird. That the farming of such birds is a practicable scheme has been demonstrated by the National Association of Audubon Societies in the United States, which established a colony on a small island in the Stono River near Charleston, and in 1917 the colony was tenanted by more than 400 birds. On the other hand, the egret, like other herons, subsists almost exclusively on fish, and the establishment of such rookeries would be bound to have an injurious effect on neighbouring fresh-water fishing grounds.

The European markets still are able to obtain large

quantities of such birds as humming birds, egrets, rheas, and so on from South America.

**Bird Encouragement.**—A rational system of bird protection should not confine itself to the enactment of legislative protection measures that are too often allowed to become a dead

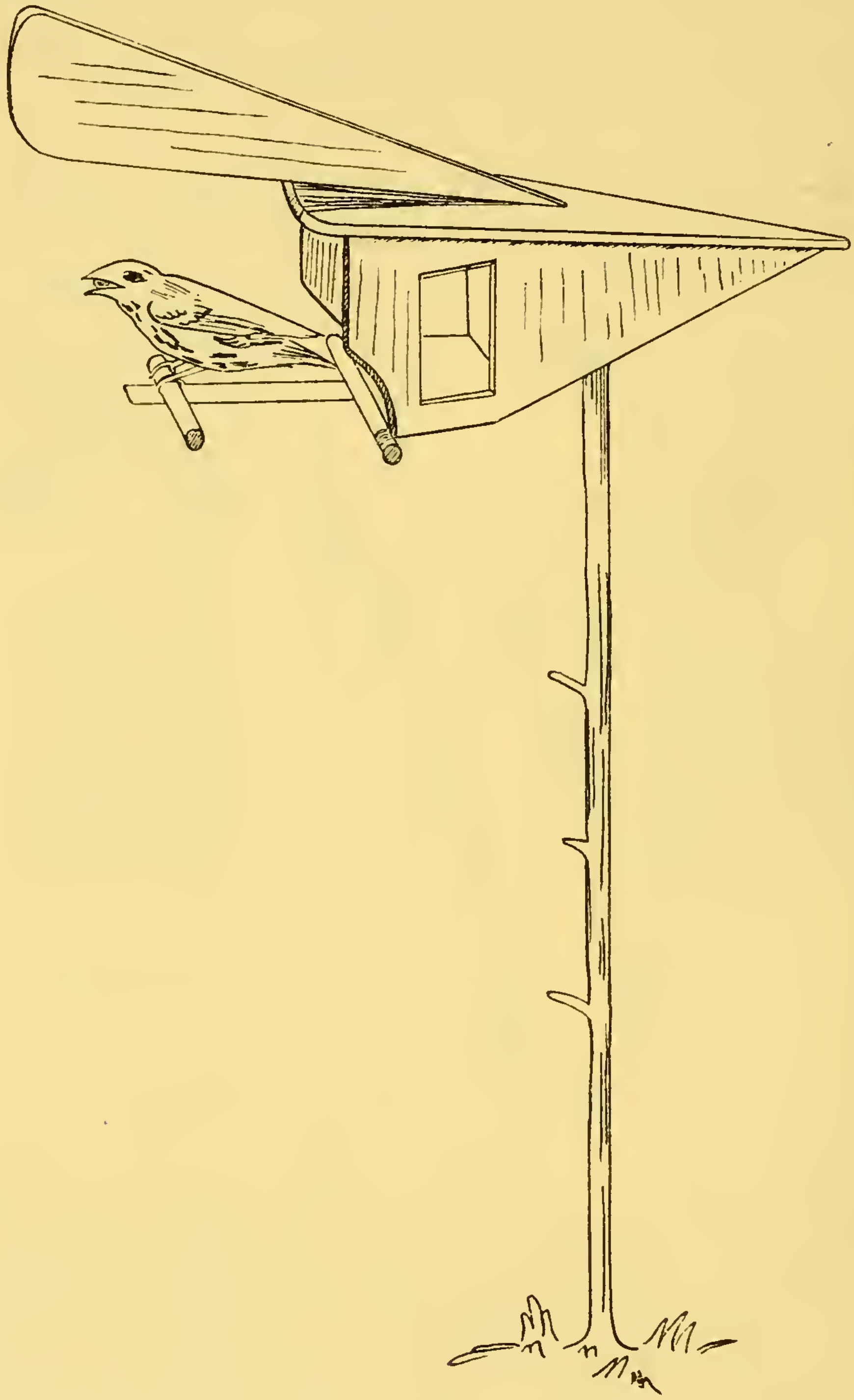


Fig. 36.—A Good Type of Bird Food Station. (After Beal.)

letter, but should include *active* measures that will tend toward an increase quantitatively and qualitatively in bird life. This can only be done by the creation of bird sanctuaries, definite reservations for bird life, ranging in size from huge tracts of country down to artificial coppices in the public parks of urban districts. Within the bounds of such reservations the Bird Protection Laws must be rigidly enforced; outside the bounds

the laws could be relaxed sufficiently to avoid hampering the agriculturist. The number of such bird sanctuaries is on the increase in most countries.

In such sanctuaries the conditions should approximate as closely as possible to those of the woodland, the swamp, or the precipitous sea island. Clean forestry is incompatible with bird profusion. Decayed and fallen trees, plentitude of brushwood, standing pools and meres should not merely be tolerated but should be supplemented by the provision of nesting facilities, whether in the form of artificial boxes, or niches in masonry, or dense impenetrable thickets of thorny shrubs.

Many nesting boxes of different types have been invented. Such birds as the wryneck, woodpecker, or stock-dove prefer the Berlepsch type of box, invented by Baron von Berlepsch of Eisenbach in Thuringia, with its bottle-shaped cavity and pointed oval base. Other birds, tits, robins, starlings, flycatchers, and the like, will nest in any sort of flat-bottomed bird box roughly constructed from slabs of refuse bark (Figs. 34, 35). Other birds prefer the half-open type of box. Many birds, of course, will not use a box at all but nest in thickets or on the ground, so that special protection from predatory mammals is desirable where the sanctuary is small.

It may be added, in conclusion, that the indiscriminate protection of all birds in a natural sanctuary may, and often does, lead to a superabundance of hardy, virile species at the expense of less adaptable birds. Thus, in a gullery, the protection of the egg-eating, nestling-eating herring gull militates against the encouragement of kittiwakes, guillemots, razor-bills, and puffins ; the presence of peregrine falcons or jackdaws discourages the chough ; on the Orkney and Shetland Islands, protection of the great skua has been inimical to whimbrels ; on the Ferne Islands, herring gulls have discouraged the development of the tern colonies. It may be added further, that natural factors such as food shortage, floods, and so on, and such necessary artificial causes as lighthouses, are responsible for more wholesale loss among birds than is caused by direct human agency.

## CHAPTER XXII

## ANIMAL DOMESTICATION

The original wild types from which domesticated animals have descended are, in many cases, to be recognised only with the utmost difficulty and doubt, so long is it since they became tamed to the service of humanity. In many cases domestication must have commenced in early Neolithic times, so that there is every possibility that the original wild type has died out. Certainly, with the exception possibly of the ostrich and the African elephant, there is no example in modern times of the domestication of a large wild animal.

Further, the distinction that we make between animals of draught or burden, animals of food or milk, animals of value in hunting, and so on, probably did not exist among the early domesticators of animals.

Neolithic man would require a general utility animal, an animal that could serve equally well for burden or for help in the chase or, if need arose, for food. Thus the dog and the horse were probably among the first animals to be tamed. Cattle, sheep, goats, swine came later. Domestication of birds later still.

In Europe, domesticated animals were not possessed by Paleolithic man, with the doubtful exception of the horse and the dog, but were introduced by invasions of Neolithic peoples, some of whom came into Europe from the Central Asiatic plateaux, others from the direction of Asia Minor, others again possibly from the region of Northern Africa.

Thus, animals whose domestication dates from Neolithic times, such as the horse, ox, sheep, dog, are represented to-day by a vast number of breeds derived by the hybridisation of domesticated types, themselves produced in different centres of domestication from different wild species. That is to say, they have originated from a number of ancestral species, most of which may to-day be extinct.

On the other hand, in the case of animals whose domestication has occurred probably since Neolithic times, and which have not become widely distributed, the breeds are few and not greatly different from each other, and the wild ancestor may be

looked for in one or two species, often still living. Such is the case, for example, with the elephant, yak, llama, reindeer, and many domesticated birds.

To-day most of man's work is carried out by ten animals, five of which—the horse, ass, mule, ox, and dog—are of world-wide distribution, the remaining five—elephant, yak, llama, reindeer, and camel—being of local distribution. His meat supply is furnished chiefly by various species and breeds of *Bos*, the ox, of *Ovis*, the sheep, and of *Sus*, the hog, supplemented in various localities by the goat, reindeer, rabbit, and domesticated birds. Valuable products are supplied by the sheep, milch cow, rabbit, ostrich, and so forth. Useful services are supplied to him by the dog, cat, cheetah, and so on.

**Horses.**—The term " horse," in a zoological sense, comprises the species of *Equus*, a genus of hoofed animals characterised by the possession of only one functional toe, the middle one, on each limb, the lateral toe being represented by bony vestiges. The genus includes, therefore, in addition to the true horses, the asses and zebras.

The true **horse,** *Equus caballus*, is distinguishable from the other forms by a number of minor characters, notably the possession of callosities on the inner side of the hind limbs, in addition to those on the fore limbs. These so-called " chestnuts " are probably vestigeal glands. The mane and tail are much hairier than those of ass or zebra, the head proportionately smaller, and the coloration, except in very rare cases, does not show striping. Apparently no truly wild individuals of *E. caballus* exist, and the species comprises some fifty or sixty domesticated breeds or races.

The asses and zebras differ from the domesticated horse in the characters mentioned. They resemble one another in having a more or less striped coloration, more pronounced in the zebra than in the ass.

Living species of asses comprise :—

The **onager** (*E. onaga*) of the deserts of Persia and North-western India, and the very similar **hemippus** (*E. hemippus*) of Northern Arabia and North-western Persia, yellowish animals with a dark mid-dorsal stripe ; they are extremely swift animals and are said to be impossible to domesticate.

The **kiang** or Dzeggetai (*Equus hemionus*) of the high plateaux of Thibet and the region east and south of Lake Baikal ; this is a dark, shaggy-coated animal with a dark erect mane and a dark mid-dorsal stripe ; the **Abyssinian ass** (*E. asinus*) of Abyssinia and the Nubian desert, with a mid-dorsal stripe and

a horizontal shoulder stripe; the **Somali ass** (*E. tæniopus*) of Eastern Somaliland, a greyish animal with no shoulder stripe, a very faint dorsal stripe, and with cross stripes on the legs.

Of the zebras, which are all African in distribution, there are six or seven acknowledged species, the best known of which are: the **Grevy zebra** (*E. Grevyi*) of Southern Abyssinia and Somaliland; this is the largest of the zebras, and is characterised by the narrow, brilliant dark-brown stripes on a silver-grey ground, the very long head and the hairy ears; the stripes do not meet along the under surface of the belly: **Grant's zebra** (*E. Granti*) of British East Africa, on the other hand, has broad, brilliant stripes completely surrounding the body and uniting with a mid-ventral dark line, and has a conspicuous set of horizontal stripes extending down the legs to the hoofs; this zebra, together with the extinct **Burchell's zebra** (*E. Burchelli*), and the extinct **quagga** (*E. quagga*), both of South Africa, formed a group of allied species extending in range from the north of British East Africa down to the Cape of Good Hope, and showing a transition between the universal striping of the Grant's zebra and the limited striping, on shoulders only, of the quagga: the **Mountain zebra** (*E. zebra*), now very rare, and carefully preserved by the South African Government, has also very broad stripes and is characterised further by a broad gridiron of transverse stripes over the hips, by a short head, very long ears, and very short, heavily built limbs.

The modern breeds of **domesticated horse** (*Equus caballus*) seem to represent the intermingling by generations of hybridisation of three distinct types of wild ancestral horse, namely:—

(*a*) A **forest type,** represented probably by the extinct *E. robustus*, whose bones and pictured representations occur so freely in the excavations of Solutré in France. It was a horse adapted to life in woods and thorny thickets, and to narrow paths amidst wet and marshy ground. It was a thick-set animal, coloured probably dark yellow, with darker stripes on face, body, and legs, with short neck, straight nose, long prehensile upper lip, thick projecting lower lip, long and flowing mane and forelock, dark wavy coarse hair, no lock of hair at the root of the tail, very rounded hindquarters, wide hoofs, hairy fetlocks. This type may be represented considerably to-day in the Norse horse (*Equus caballus typicus*), and to a lesser extent in the Highland pony, the Ardenne and Flemish black breeds, the Clydesdale, Shire, and Suffolk heavy breeds, and the Connemara pony.

(*b*) A **steppe type,** represented by the sole living type of

wild horse, *Equus przewalskii*, of the Gobi and Altai deserts of Central Asia. It is a horse readily distinguishable from all modern breeds by the entire absence of forelock, by the short upright mane similar to that of asses and zebras, and by the mule-like tail with short stiff hairs on the upper portion. It has a sheep-like nose, bent downwards and enabling it to feed conveniently on the short grasses of the steppes. Traces of this type may possibly exist in the Connemara pony, Clydesdale, Welsh, and Shetland ponies.

(*c*) A **plateau type,** descended perhaps from *E. siwalensis* of the Indian Pliocene. It was probably a slender type, fifteen hands high, and not unlike an inferior modern Arab horse. It had possibly a long flowing mane and forelock, a bunch of hairs at the root of the high-set tail, a small straight head, and slender, fine bones. It has left representatives in the modern Arabs and Barbs, and through them in the modern Thoroughbred; in the Mexican ponies; and in the so-called Celtic pony of Iceland; the latter breed represents, according to Cossar Ewart, a species which branched off at an early period from the Arabian or North African stem and spread northwards, becoming dwarfed in adaptation to a severe climate, but retaining many characteristics in common with the present Arab breeds, such, for example, as a similar shape of head, absence of hind chestnuts, and absence or reduction of the fetlock callosities (ergots).

The **Ass** (*Equus asinus*) may have been domesticated as early as the horse, but if so its distribution must have been more localised, for there is no record of its use in Western Europe before the Neolithic period.

The general opinion is that modern breeds of ass are all derivable from the Nubian wild ass of North-eastern Africa, and are quite distinct from the Asiatic onager and kiang. These latter forms seem nearer to the Przewalskii horse than to the African wild ass.

**Cattle.**—The term " cattle " may be applied to the members of the Bovine section of the Bovidæ, a family of hollow-horned ruminant animals which includes oxen, sheep, goats, and antelopes.

The true oxen form but a single genus, *Bos*.

The earliest known remains of domesticated cattle are those from the early Neolithic remains of Anau in Turkestan, and date from about 10,000 B.C. They seem to represent a domesticated variety of *Bos primigenius*, the giant black wild ox which inhabited the forests of Northern Europe and Asia in Pleistocene times.

Similar domesticated varieties of this type had reached China, Chaldea, and Babylon by 4000-3000 B.C. The type may be represented to-day by the Ankoli cattle of Uganda, themselves descended possibly from the Ancient Egyptian cattle; by the Roman ox, the Polish cattle, the Castilian and, to a lesser extent, the Andalusian breeds of Spanish fighting bull, the Hereford cattle of Great Britain, and the semi-wild Chillingham and Chartley Park cattle of Great Britain. The earliest European domesticated breed was the so-called Celtic Shorthorn (*Bos longifrons*), sometimes described as a dwarfed variety of the *Bos primigenius*, but more likely a hybrid between the latter and some eastern strain of hump-backed type. It is represented to-day particularly by the Kerry breed of Ireland, the Scottish Mountain breeds, and to a lesser extent by Dutch and North German cattle. An eastern strain is present also in the gallego cattle of North Spain.

The origin of the various breeds of Asia and Africa is unknown. Such breeds differ from those descended from *Bos primigenius*, in the lyrate shape of the horns, which grow upwards and backwards, rather than forwards, and may be very large. Other characters of the humped cattle, apart from the hump, are the large dewlap and the white rings round eyes and fetlocks (Fig. 37). Such characteristics appear in the North Spanish and other light-coloured South European cattle.

The true Asiatic and African zebu or humped cattle are generally considered as belonging to the distinct species *Bos indicus*, represented by the cattle of India and the Galla, Nuer, Moshi, and Hausa breeds of Africa.

A domesticated or semi-domesticated breed of the wild Asiatic buffalo (*Bos bubalis*) occurs in India, China, Java, Malay States, Egypt, Hungary, Italy, and Spain, under the name of the "water buffalo," and is used for milk, which is richer than that of the ordinary European cattle, for agricultural and for draught purposes (Fig. 37).

A domesticated breed of the wild Gaur (*Bos gaurus*) occurs among the hill tribes of North-eastern India under the name of the *Gayal*. Throughout Malaya the domesticated cattle are domesticated Bantings (*Bos sondaicus*). Large numbers are exported to Singapore for food (Fig. 37).

The Yak (*Bos grunniens*) is a long-haired peculiar type confined to the Thibetan Plateau, and occurring there in domesticated form.

No attempts seem to have been made to domesticate the African wild buffalo, despite the enormous value of an indigen-

ous domesticated animal in the tsetse fly belts of Central Africa, and the Water Buffalo does not seem to thrive south of Upper Egypt.

**Sheep and Goats.**—The difficulty in deciding from what

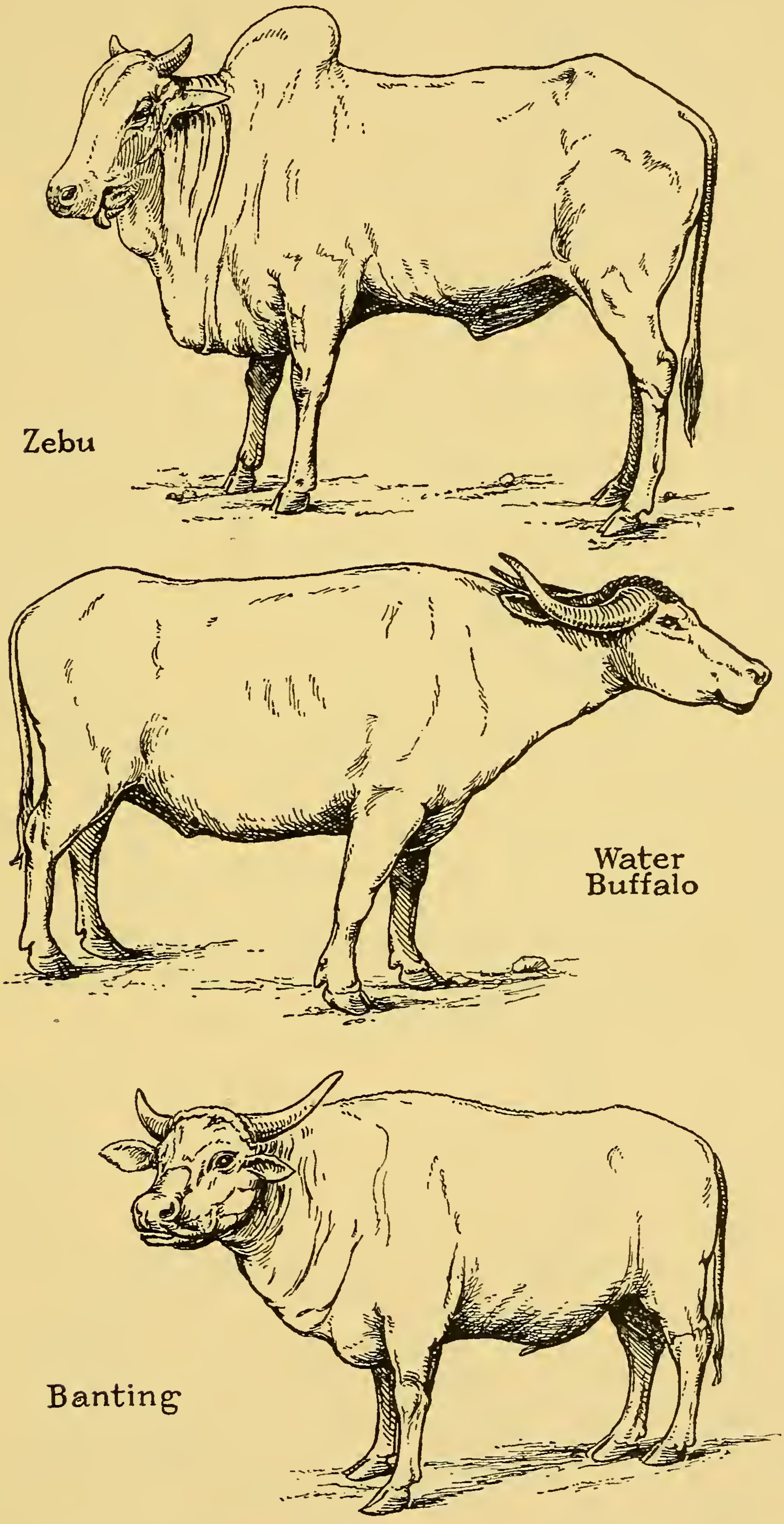



FIG. 37.—Types of Asiatic Cattle. (After Keller.)

wild types the present-day races of domesticated sheep have originated, arises not so much from the fact that no wild sheep are known to possess wool, since many domesticated breeds have a coat of hair or a mixture of hair and wool, but from the fact that all wild sheep are short tailed, whereas most domesticated breeds are long tailed. If the long-tailed condition be a character acquired during domestication, as are the woolly coat and the lack of horns in some breeds, then, at any rate for Europe and Asia, the origin of domesticated breeds from types akin to certain living types can be postulated.

There would seem to have been two centres of domestication. In the Mediterranean region of prehistoric Europe the type domesticated was probably some species now extinct but akin to the present-day "mouflon" (*Ovis musimon*) of Corsica, or to the Armenian mouflon (*O. orientalis typica*). On the other hand, in Persia or in Central Asia, the type domesticated was akin to the present-day "urial" (*Ovis vignei*) or to the Steppe Sheep (*Ovis arkal*). The Asiatic types of domesticated sheep were probably brought into Europe by the Neolithic races. Possibly the "Peat sheep" of the Swiss lake dwellings, a small sheep with goat-like horns, was of this Asiatic type (Fig. 38).

Domesticated goats differ from sheep in the absence of a face gland below each eye, in the absence of pits for these glands on the facial part of the skull, in the absence of inter-digital glands from the hind feet or even from all feet, and by the presence of a beard in the male. The horns, too, are usually sabre-like or twisted corkscrew fashion, whereas those of sheep are twisted spirally in a more or less horizontal plane. There are, however, hornless breeds of goats lacking a beard, and there are species of wild sheep without face glands, so that it is not always possible to draw a strict line of demarcation between the two groups.

Most domesticated goats (*Capra hircus*) are considered to be derived from the "Bezoar," *Capra hircus œgagrus*, of the Mediterranean Islands, Asia Minor, and Persia. The Cashmere breed, however, may be derived from the "markhor" (*C. falconi*) of the Himalayas, and the Angora breed may represent a mixture of these two types.

**Dogs and Cats.**—Both the dog and the cat offer an example of a domesticated animal originating from a number of wild ancestral species, domesticated independently in various centres.

In the case of the dog, there can be little doubt that the various breeds which exist to-day have arisen through the indiscriminate hybridisation of different types of domesticated

dogs, originating in widely separated centres from ancestral species of present-day jackals, coyotes, and wolves. There is no near kinship between dogs and foxes.

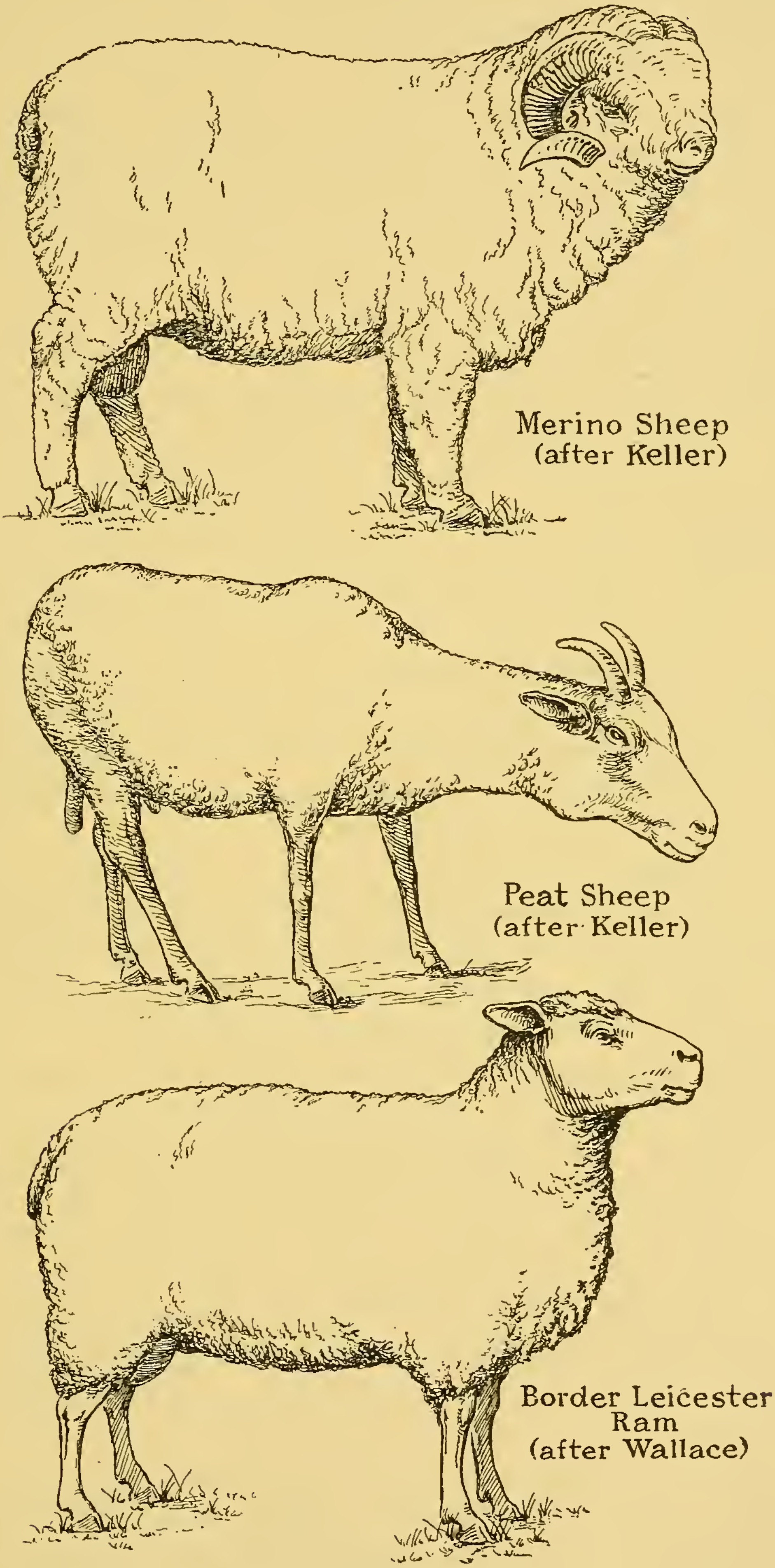



Fig. 38.—Types of Sheep.

The dog of European Neolithic dwellings was of the jackal type, and hybridisation between such a type, brought possibly by Neolithic races from the east, and local varieties of wolf, would account for most modern breeds. The original ancestor of the Neolithic importation may have been an ancestral form of the Indian wolf (*Canis pallipes*).

In glacial deposits near Lake Bologoia in Russia, remains of a wolf-like dog (*Canis pontiatini*) have been discovered. This may have played a great part in the ancestry of European dogs. Thus the Bronze Age dog (*Canis matris optimæ*), a collie or sheep-dog type, may represent a cross between a European race of wolf and *C. pontiatini*.

The cat, similarly, represents a composite product resulting from the hybridisation of distinct types of domesticated species of *Felis*. The chief source of the European breeds of cat was probably the Egyptian cat, a domesticated form of *Felis ocreata*, whose sandy or tortoise-shell colouring characterises many European cats. This cat interbred in Europe with the wild cat (*Felis catus*) and produced the blotched or tabby varieties of cat. European cats have been also affected by Persian and Indian importations, representing domesticated races possibly of the Bokharan Steppe Cat (*F. caudata*).

**Other Domesticated Animals.**—In the case of the remaining types of domesticated animals, there is little difficulty in deciding as to their wild progenitor.

There is little doubt that all the European and North American varieties of domesticated hog have originated from the Wild Hog (*Sus scrofa*) of Europe, Asia, and North Africa, although young hogs of domesticated breeds do not show the stripes characteristic of many young wild swine.

The llama and alpaca of South America are varieties of the wild camel *Auchenia vicugna*. The Indian elephant is a tamed *Elephas indicus*. The domesticated races of rabbit, rat, guinea-pig are all easily derivable from living wild species. Domestic breeds of poultry descend from the Red Jungle Fowl (*Gallus bankiva*) of Northern India, Siam, Cochin China, Malaya.

Ducks and geese originate from the Mallard (*Anas borcas*) and the Gray Lag (*Anser ferus*) respectively. Pigeons, in spite of the great variety of races, all originate from the Blue Rook (*Columbia livia*).

The camels, however, cannot be derived from any known wild ancestor, since the so-called wild camels of Central Asia are feral, that is to say, descended from domesticated forms.

**The Possibilities of Domestication.**—With the exception of

the pigeon and the ostrich, man has not succeeded in modern times in domesticating any wild species of mammal or bird, despite the fact that there are several types which offer great possibilities in this respect. Notable examples of such types are the musk ox and bison of North America, the zebra, eland, and elephant of Africa.

The **musk ox** (*Ovibos moschatus*), an animal intermediate in most respects between cattle and sheep, and about the size of a small ox, is peculiar to the Arctic regions, although its former wide range has become limited to Northern Canada, some of the islands of the Arctic, and Greenland, owing to the depredations of Eskimos, Indians, and white traders. In fact, the animal is rapidly becoming exterminated, although the Canadian Government is endeavouring to protect it. The animal's body is covered by long hairs, arising through a thick coat of under fur, and the value of its skin to the trader is the main reason for its decrease in numbers.

The value of this animal as a potential domestic animal has been urged by several authorities, notably by the explorer Stefansson, who has pointed out that the animal is readily tamed, inoffensive, a meat producer, milk producer, and wool producer, and the only large animal except the reindeer which in domesticated form can withstand the climatic conditions of the northern fur-producing regions. In Alaska and Northern Canada, for example, such an animal would be of tremendous value if it could be readily domesticated and reared.

The domesticated **reindeer** of Europe has, it may be added, been introduced into Alaska with very great success by the United States Government, and they are now extremely abundant, the consequence being that nomadic tribes of fishers and hunters are rapidly becoming converted into raisers of reindeer and self-supporting herders and teamsters. The method adopted was the establishment of reindeer stations, under skilful Lapp or Finn instructors, centring around the various mission stations. The reindeer is now the basis of an established livestock industry employing large numbers of the native population, and reindeer meat and tanned skins are shipped to the cities of Canada and the United States.

The introduction of reindeer from Norway to Newfoundland was similarly carried out by Dr Grenfell, and the imported herd increased; but lack of Government support, either financially or in checking poaching, ruined the experiment, and the remaining animals were transferred to the north shore of the Gulf of St Lawrence in 1918, where, under the protection of

the Canadian Government, they are increasing rapidly in numbers.

The surplus stock of **bison** which has resulted from the successful measures adopted by the Canadian Government to protect this animal, has brought forward the question of the possibility of domesticating this animal. It is an animal producing meat and skins of great value, an animal pre-eminently adapted to the treeless, blizzard-swept prairie regions, and an animal that can be readily crossed with the domestic cow to produce a hybrid, the *cattalo*, which is resistant to Texas Cattle Fever. Experimental work by the Division of Animal Husbandry of the Canadian Department of Agriculture has shown that certain initial difficulties, particularly sterility and abortions, in the raising of cattalos can be overcome, and a very thriving herd of cattalos is now located in Alberta. Experiments are also being made in the crossing of bison with the yak.

Attempts to domesticate the **eland** in Africa have not been successful, as under ranch conditions in Africa it seems very susceptible to cattle diseases such as rinderpest, and in captivity in European countries does not breed freely.

In Africa practically nothing has as yet been attempted towards the establishment of a domestic race of draft or of food animals suitable to the conditions of the tsetse fly-belts, despite the enormous value of such an animal in the development of these areas of Africa.

The **zebra** is capable of hybridisation with the ass or the horse, but the zebrule so produced is somewhat intractable in harness and has not the strength and endurance of an ordinary mule.

As regards the **elephant,** attempts have been made since 1905 by the Belgians to domesticate young elephants at Agri in the Uele River District of Belgian Congo, with a certain degree of success, about a hundred animals now being employed there in carrying bricks, dragging timber, and so on.

There are several difficulties in the way of large scale domestication of the African elephant. It must be remembered that in India domesticated elephants are not obtained by ordinary stock-breeding methods, but are obtained by the taming of wild adult elephants captured in a huge stockade trap called a keddah, and the capture of a herd of wild elephants is a long process employing a great number of trained beaters and trained domesticated elephants.

The African negro would be useless as a keddah man or as a mahout, and the large scale capture of elephants in Africa

would necessitate the importation of a keddah staff of men and trained elephants from India, an enormously expensive process; as a matter of fact, the African elephant can travel so fast and so far that it is doubtful whether a wild herd could be captured by keddah methods.

Again, in India the value of domesticated elephants is due largely to their employment in such work as the loading of teak logs. The use of elephants merely as beasts of burden would be uneconomical.

In India the daily ration of an elephant comprises 860 lbs. of sugar cane and 60 lbs. of flour chappaties; that is to say, an elephant eats more than 900 lbs. of food per day, and it will carry a load of 12 cwt. at a pace no faster than a man's walk, whereas the same load could be carried as fast and as far by twenty-four porters, who in one day would require only 48 lbs. of food altogether.

It must be noted, too, that elephants require a great deal of water, and many of the African safari routes are deficient in this for a good part of the year.

Nowhere in Africa is the timber industry sufficiently developed to justify the capture and feeding of elephants for that purpose alone, and for any other form of work the animal is uneconomical.

Certain species of deer probably offer the most favourable prospects of domestication in the future. Complete domestication is not necessary; animals kept in large preserves with surroundings as nearly natural as possible would be as profitable as a domestic herd to a breeder, and would probably be a great deal healthier. Past experience has shown that certain species can be acclimated very readily in new areas. Such has been the case, for example, with the Axis deer, the Japanese and Pekin Sika deer, the red and fallow deer of Europe, the North American wapiti, and Virginia deer.

The wapiti or elk appears to adapt itself readily to almost any environment, and will breed as freely within the narrow limits of a menagerie paddock as in its native environment.

# CHAPTER XXIII

## TYPES AND BREEDS OF FARM ANIMALS

EVEN the briefest description of the multifarious breeds of domesticated animals and birds that occur in the world would extend far beyond the limits of this chapter, and for that matter beyond the limits of the whole book itself. This chapter, therefore, will concern itself merely with the salient features of the breeds of horses, cattle, sheep, pigs, and poultry that occur in the agricultural districts of Western Europe and North America. It must be pointed out, however, that in limiting description to the farm animals of these areas, no injustice is done to the question of stock-breeding as a whole, since the livestock breeds of Europe, and particularly of Great Britain, are easily the most important of the world's breeds of domesticated animals, if one may judge by their distribution over the world's surface and by the financial value of the livestock breeding industry in Western Europe and North America.

It may be noted that the pre-eminent position held formerly by British livestock breeders as exporters of pure bred stock has been encroached upon considerably of late years by stock-breeding industries established in North and South America, in South Africa, and in Australia, where improved types of West European livestock have been created. One may instance the Corriedale breed of sheep in New Zealand, the Australian Merino sheep, the Australian improved Orpington or so-called Australalorp breed of fowl, the Australasian dairy shorthorn and Friesian strains of cattle, the American Wyandotte and Rhode Island breeds of fowl, Poland-China and Duroc-Jersey and Chester-White breeds of hog, American Percheron horse, and American Merino sheep.

**Horses.**—The breeds of domesticated horses can be divided into two groups, namely, **heavy horses** and **light horses**; the second of these groups may be further subdivided into the **Driving Class** and the **Riding Class,** the heavy types being all classed as **Draft** horses (Fig. 39).

Of the draft breeds, the chief are the Shire, Clydesdale, and

Suffolk of Great Britain; the Percheron of France; and the Belgian draft horse.

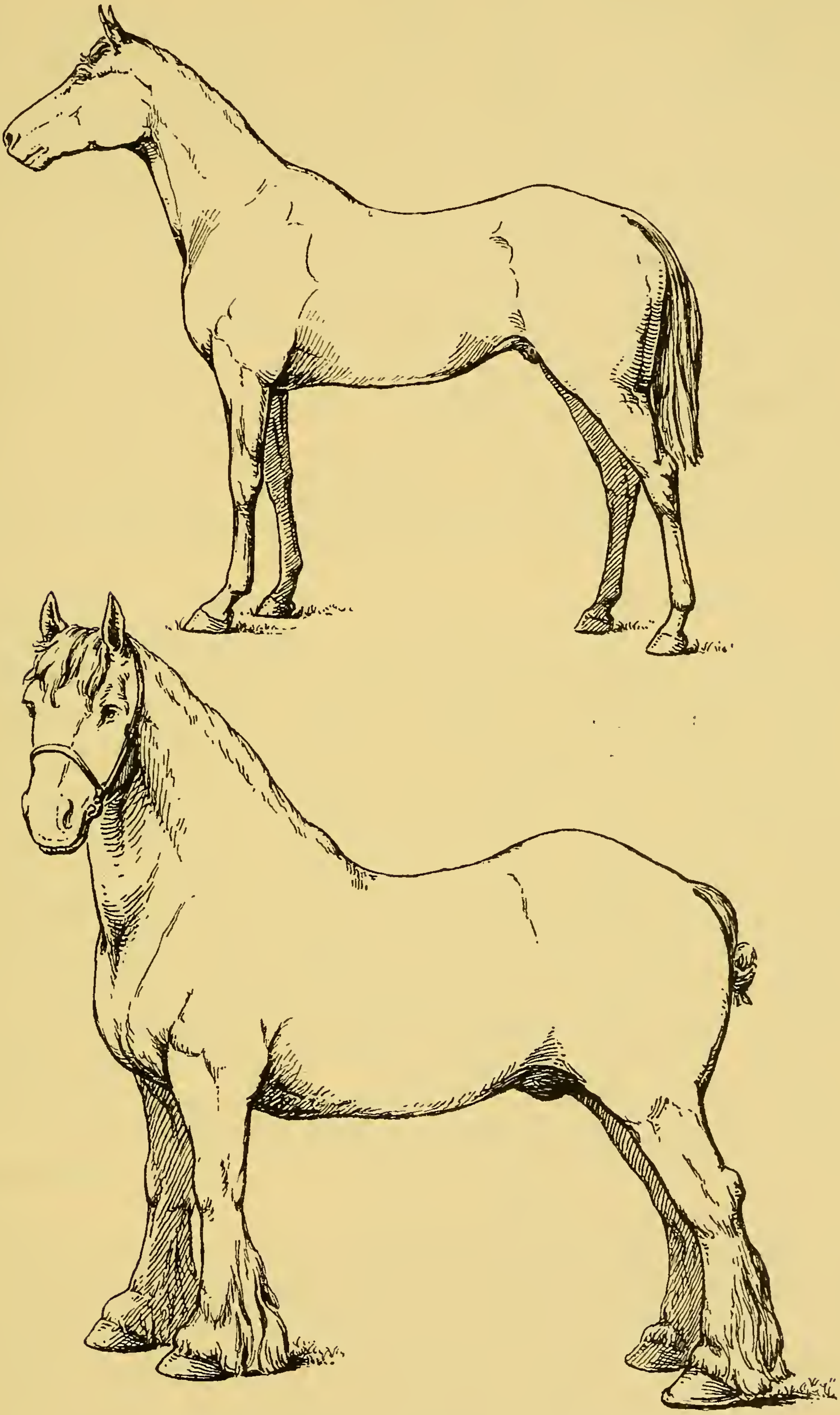


Fig. 39.—Light and Heavy Types of Horse.

As regards the light horses, there are a number of different breeds. The most important are the Thoroughbred, Arab, Hackney, Cleveland Bay, Yorkshire coach horse, and the

Mountain and Moorland ponies of Great Britain ; the Standard-bred or American trotter ; the Orloff or Russian trotter ; and the Oldenburg or German coach horse.

The **Shire** horse, which takes its name from the south-eastern counties of England, is the modern representative of the old English Black Horse or Great Horse, a native breed whose size and strength was increased by importation of large built horses from Flanders and Germany during the reigns of Norman and Plantagenet kings in order to produce a horse capable of carrying a man in heavy armour. The invention of gunpowder relegated the Shire horse to agricultural purposes.

This breed is the largest and heaviest breed of horse, and finds its chief use to-day in draft work in the seaports and manufacturing towns of England. The export trade in Shires has fallen off, owing to a slackening of demand from North America, where the breed is considered to be rather too heavy and slow moving, and its hairy legs rather a handicap on muddy land.

The **Clydesdale** is a native of Scotland and is used commercially for lighter draft work, especially in the northern ports of Great Britain. There is no doubt that the Clydesdale has been influenced by Shire blood. There is very little difference between a well-bred Clydesdale and a Shire, beyond the possession by the former of cleaner, flatter bones and less feather on the legs. The Clydesdale, however, is slower in coming to maturity but has a longer working life. In both breeds the prevailing coat colours are bays and browns. On the whole, however, it is safer to regard both types as belonging to the one breed, and it would probably be to the advantage of both if they were amalgamated and registered in one stud book. The tendency towards loss of size in the Clydesdale and towards coarseness in the Shire could be counteracted by the use of Clydesdale stallions on Shire mares.

The Clydesdale is a popular breed in Canada, where it rivals the Percheron in the public esteem.

The **Suffolk** horse is indigenous to the eastern counties of England, and until recently its distribution was quite local. It has a thick-set body and short legs, and from its appearance it has received the name of Suffolk Punch. There is no feather on the legs, as with Shires and Clydesdales, so that the leg does not become caked with mud from agricultural lands. While there is no question that the Suffolk is a hard worker, there was not long ago a prejudice against it in the districts of England, outside East Anglia, on account of its supposed stupidity.

The **Percheron,** which gets its name from the La Perche district of Normandy, France, is very similar in build to the Suffolk, but the body and legs are more in proportion. The coat colour is grey or black, and the legs are without feather. The origin of the breed is not certain, but apparently native horses were improved by Arab and Barb blood, and later by importation of horses from Belgium and Denmark.

The Percheron is now the most numerous and popular of the draft breeds in the United States. Its advantages lie in its clean limbs and its slightly greater speed than the Shire and Clydesdale. In Great Britain the breed is not widely known.

The **Belgian** draft horse bears some resemblance to the Percheron, but the chest is fuller and the body deeper and broader. The legs are clean, but there is a tendency towards small, narrow feet. The prevailing colour is chestnut, although bays, browns, and roans appear. It is a very ancient breed, famous throughout the Middle Ages, and imported into England to improve the Old English horse. It is specially suited for heavy draft work on the Belgian quays, although its action is rather slow.

The **Thoroughbred** or English racehorse is of mixed origin. There were running horses in England before the Stuart kings, but the foundation of the breed is due to Charles II., who imported Eastern mares, the so-called Royal mares. The three present lines of Thoroughbred descent originated from three famous sires—the Byerley Turk, imported in 1689; the Darley Arabian in 1706; and the Godolphin horse of 1724. The influence of Barb, Arabian, and Turk combined, with the drastic selection of racecourse competition, has produced the modern Thoroughbred with its long limbs and greyhound appearance. Coat colour is generally bay or brown, less commonly chestnut or grey and, rarely, black. The value of the Thoroughbred is not confined to racecourse work but is applicable to the improvement of almost all breeds of light horses.

The **Arab** horse, to which the English Thoroughbred owes so much, is, as its name implies, an Eastern breed, but its origin is not clear. Whilst it is probable that horses existed in Arabia at a very early period, it is not certain that the Arabs possessed this type until after the commencement of the Christian era. The Arab type has always been kept pure, and no animal is considered as pure bred unless it can be traced back to the five mares of Al Khamseh.

The characteristics of the breed are similar to those of the

Thoroughbred. The rather broad forehead with prominent eyes is very distinctive. The hardiness of the Arab horse is traditional, for in endurance trials it has no rival. As in the Thoroughbred, the predominant coat colour is bay, but greys, browns, and chestnuts are common. The breed has been introduced into Spain, England, America, and Eastern countries, but apart from its influence on the Thoroughbred, the Arab has been little favoured in Great Britain until recently.

It is a matter of convenience, at this juncture, to refer to the **Hunter,** which, although not a distinct breed of horse, deserves some description on account of its use and value.

Since the greater number of Hunters are not pure bred, there is some variation in type. Constitution is of great importance. owing to the arduous nature of its work, and in consequence an Arab cross is particularly valued. While the very best Hunters must necessarily be thoroughbred or nearly so, a cross-bred animal suits the requirements of the majority of followers of hounds. A useful Hunter can be obtained from a Thoroughbred sire and a light cart mare, but probably the best cross is between a good Hunter and a Thoroughbred. In Great Britain there is a Hunter's Improvement and National Light Horse Breeding Society which has the object of improving and promoting the breeding of Hunters, whether for riding or driving or for military requirements.

The **Hackney** is native to the eastern countries of England, and is usually believed to have originated at the end of the nineteenth century from crosses between the early Norfolk Trotter and the Shules or Shields horse, which gave an infusion of Arab blood. While the Hackney was first associated with the eastern countries, it spread into Yorkshire and became a distinct strain, the Yorkshire Hackney.

The Hackney, which is well known to the sight-seeing public at agricultural shows on account of its very showy action in trotting, stands at a height of 15·2 to 15·3½ hands, and its general appearance indicates considerable strength. It is a popular export breed, and finds numerous buyers in North America and the Argentine.

The **Cleveland Bay** is indigenous to Yorkshire and is a large size carriage horse. The breed was highly esteemed in the middle of the nineteenth century, but was faced with extinction by the advent of railways and the disappearance of the stage coach. Fortunately, however, it is suitable for farm work, and so the breed has been saved. The animal stands 16·1 to 16·2 hands high, has good sloping shoulders, short legs, oval back,

powerful loins, and long quarters. The colour is bay. A white blaize or white foot is an indication of foreign blood.

A later breed, arising in the same area, is the **Yorkshire coach horse.** It is probably a branch of the Cleveland Bay breed, and is similar to it but is taller, and has a higher and more free action. While of course there is a reduced demand for coach horses owing to motor transport, the ruling prices indicate that a good class coach horse of exceptional appearance, as is the case with the Yorkshire breed, will always find a market.

There are a number of distinct breeds of **ponies** in the mountain and moorland districts of the British Islands. While differences in size and appearance occur, a common origin of the British forms is probable. The various breeds—Welsh, New Forest, Dartmoor, Exmoor, Fell, Dales, Shetland, Highland, and Connemara—are distinguished by their hardiness, their adaptability to severe climate and poor food, and their great strength. While the conditions of their existence make them surefooted and active on rough ground, these conditions are disadvantageous in that indiscriminate breeding under them produces such defects as ewe-neck, low withers, narrow quarters, and sickle hocks. In this connection some reference must be made to the work of the National Pony Society in Great Britain, whose aim is to encourage the production of high class riding ponies. For entry in the Stud Book, ponies must not exceed 14·2 hands high. At such a height, such a pony as a polo pony must be a powerfully built animal, since it has to carry weights which are considered ample for a Hunter.

The Standard Bred or **American Trotter** is the national horse of the United States. There is some doubt as to the origin of the breed. The grandsire of "Hambletonian," the most famous of American trotting horses, was an animal believed to be of Norfolk blood. "Hambletonian" was foaled in 1849, and, between 1867 and the present day, every trotter, except one, that has lowered the record, has had Hambletonian blood.

For registration it is laid down that the animal must be the progeny of a registered standard trotting horse and a registered standard trotting mare. If a stallion, he must have, himself, a trotting record of 2·30 minutes for the mile, or better, or be the sire of three trotters with records of 2·30, or better. If a mare, she must have a trotting record of 2·30, or be the dam of one trotter with a record of 2·30.

The American trotter is distinguished by great shoulder development, arising through the increased size of the pectoral

muscles. There is a tendency for the forefeet to come very close together in consequence, and there is a greater liability to interfere, that is to say, to strike the limb with the opposite foot when moving.

The breeding of trotting horses is an important industry in the United States, and whilst in the Atlantic States flat racing receives more attention than trotting, in the west and south the reverse is the case.

The other trotting breed is the **Orloff** or **Russian Trotter.** This breed was founded by Count Alexis Orlov-Tchetmensky at Khrenovoya, south of Moscow, and is of mixed origin. An Arab, imported from Greece in 1775, was the first great sire, and his offspring, by a Danish cart mare, mated to a well-built Dutch mare, produced the sire from which all the Orloff trotters are descended. In consequence of their ancestry, the breed is not fixed in type, the draft horse characteristics tending to appear as regards head and legs, and the Oriental blood as regards body. Of the three trotting breeds, the American is much faster than the English Hackney or the Russian trotter.

The **Oldenburger** or **German coach horse** is a light draft horse, 16-16½ hands in height. The body is rather large, with a long and arched neck, high withers and rump, and comparatively long legs. The colour is bay, brown, or black.

**Cattle.**—The history of the introduction of cattle to England has been told by Wilson. He has shown how, starting with the Celtic Shorthorn, introduced by Belgic tribes, the Romans, Anglo-Saxons, and Norsemen in the later invasions, each brought with them new kinds of stock.

The Romans introduced a heavy breed, mainly white, with black markings on muzzle, ears, eyes, and lower limbs, and with long up-turned horns. From this strain the wild white cattle are believed by some authorities to be descended. The Anglo-Saxon cattle are believed to have been small, red in colour, and to be represented to-day in the Lincoln, Suffolk, Sussex, Devon, and Hereford breeds. The Norse invasion is believed to have been responsible for the introduction of the small, short-legged, hornless or polled cattle, of dun colour, possibly represented to-day by the Aberdeen-Angus and Galloway breeds.

The modern breeds of domesticated cattle are usually grouped, according to their aptitude for producing milk or beef, into **Dairy Cattle** and **Beef Cattle.** Certain breeds which are noted for both milk and for flesh-forming characteristics, are classed as an intermediate group of **Dual Purpose Cattle.**

It must be understood that an aptitude for milk production and one for flesh production are to some extent antagonistic qualities. An animal cannot possess the best points of the

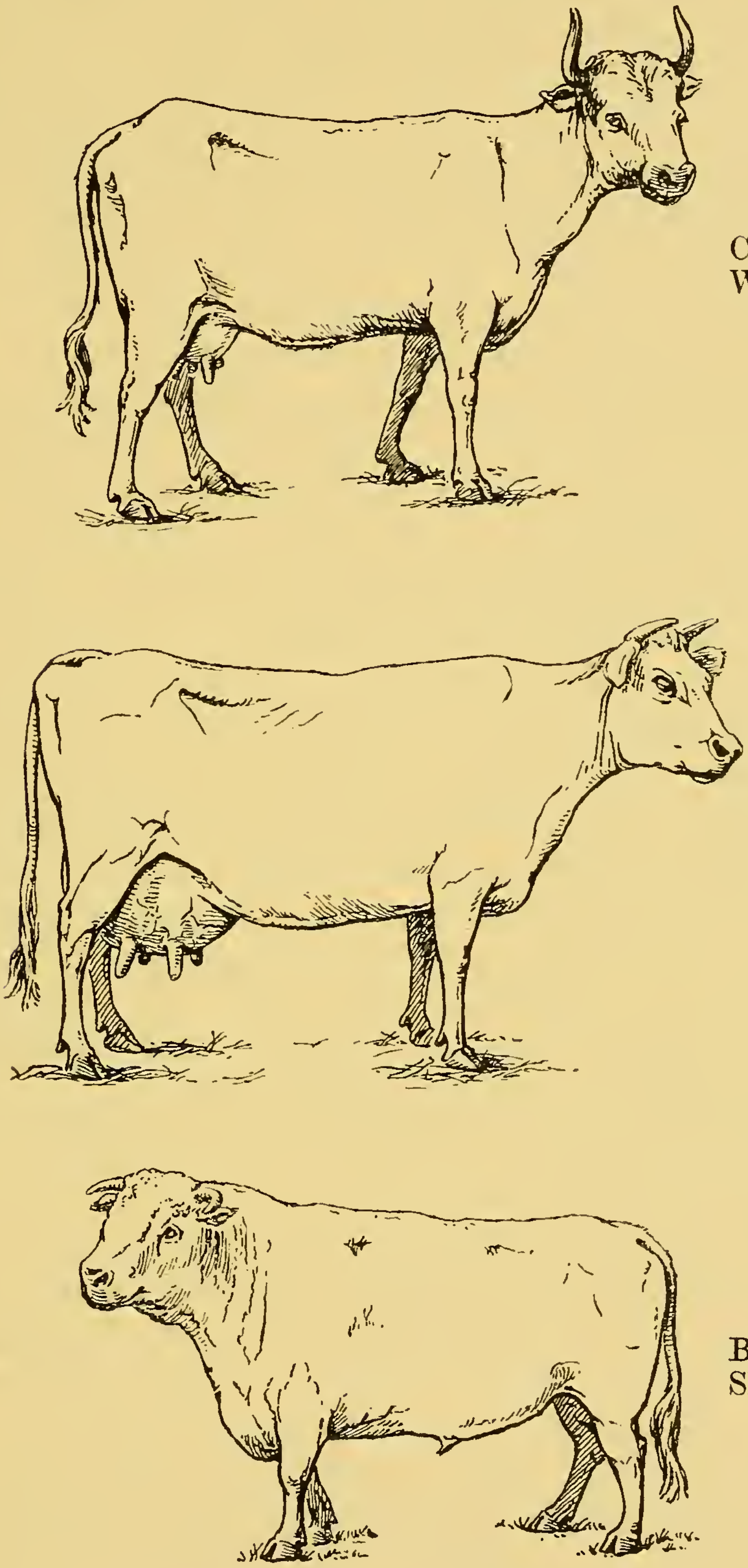



Fig. 40.—Types of Cattle. (After Wallace.)

dairy and beef breeds at one and the same time, so that this intermediate grouping, while convenient from the economic point of view, is really somewhat artificial.

A hundred years ago probably all breeds were dual purpose,

and the modern exaggerated importance attached to milk and flesh production is a consequence of the prominence at the large agricultural shows of certain breeds in which there has been a concentration either upon the production of meat or of milk. Such single purpose cattle are not bred under normal conditions on the farm, but require special attention which cannot be given by the ordinary farmer. Nearly all the prominent beef breeds are claimed to have good milking strains, and probably 80 per cent. of European cattle and 98 per cent. of American cattle are dual purpose.

Wallace, whose arrangement we follow here, divides breeds of cattle, therefore, into the two following groups :—

(*a*) *Beef Cattle*, those breeds kept mainly for beef production, and including the Shorthorn, Hereford, Aberdeen-Angus, Galloway, Devon, Sussex, West Highland, Longhorn, Welsh Black, Red Poll, Park, Devon breeds of Great Britain ; and

(*b*) *Milch Cattle*, including the Ayrshire, Kerry and Dexter, British Friesian, Jersey, Guernsey breeds.

It is desirable at this point to indicate the general characters of the Beef, Dual Purpose, and Dairy cattle.

The Beef breeds should have a compact, deep body, set low, with heavy quarters. The Dairy breeds have a refined appearance, as compared with beef cattle ; owing to the greater depth and width of the hindquarters, the general outline of the body is wedge shaped ; the dairy animal has a lean look, the body being long and not so well filled (Fig. 40). In the bull of the dairy type, a pedigree showing heavy milk production in the dam and grandams is of the greatest importance, since the quality of milk production is apparently transmitted by the female through the male line.

Dual purpose cattle, as stated above, rarely possess dairy and beef characters in the one animal ; but the name is given to breeds where the cows are good milkers, and when dry, fatten quickly and provide a good carcass. The bullocks can be readily fattened and are in demand by the butcher.

The **Shorthorn** breed, which in numbers equals the remaining breeds put together in the British Isles, originated in the north-east district of England. The history of Shorthorn breeding will be discussed in the following chapter. The success of the breed is largely due to its dual purpose character, to its suitability for various climates, and to its value in grading up native cattle in foreign countries. Some strains of Shorthorn are beef animals, but the majority of Shorthorn strains can be regarded as dual purpose. At the same time the breed

can compete with the purely dairy breeds, and there are therefore Dairy Shorthorn strains which, while being excellent milkers, will, when dry, fatten rapidly.

The Dairy Shorthorn Association in Great Britain has paid much attention to milk records, registering in this respect not only pedigree animals, but also non-pedigree animals which have authentic milk yields. It is hoped that, by mating non-pedigree cows with pedigree Dairy Shorthorn bulls, the offspring, after several generations, will qualify for registration in Coates' Herd Book, and thus increase the number of pedigree animals.

The coat colours of Shorthorn cattle are red, white, and roan. Roan arises from the red by white cross, and is the commonest colour in Great Britain. White is not a popular colour, since it is avoided by importers in tropical countries owing to the tendency of white cattle to suffer skin blistering, but white animals are used in obtaining the so-called "blue-grey" cross-bred animal, a cross between Shorthorn bull and Galloway cow.

The **Hereford** breed is, as the name implies, native to the county of Herefordshire and neighbouring districts of England. It is one of the oldest of modern breeds, and had no little reputation even before its improvement in the latter half of the eighteenth century. It is noted for its strong constitution, resistance to disease, and early maturity. The coat colour is very distinctive, the body being deep red with head, chest, and under surface pure white. Owing to its hardiness, immunity to disease, especially to tuberculosis, and its suitability for grading up range cattle, the Hereford is always in demand in North and South America. It is distinctly a beef breed, the practice of permitting the cows to suckle their calves having prevented the improvement in milk production of the breed, since there has been no selection of heavy milkers to use for breeding.

A hornless strain of Hereford has been created in the United States during the present century, and a separate Herd Book has been established.

The **Aberdeen-Angus** breed is indigenous to the north-eastern districts of Scotland. Its origin is not clear, but apparently such black, hornless cattle have existed in these districts for centuries. Its improvement started at the beginning of the nineteenth century, and the work of M'Combie of Tillyfour, Aberdeenshire, is classical in this connection. At the Smithfield Fat Stock Show, the Aberdeen-Angus has more successes to its credit than any other breed. In twenty-one years, eleven championships and five championships have been secured by the breed, and for fourteen years in the carcass

classes an Aberdeen-Angus has won the championship. This unrivalled position of the breed as a beef animal keeps it in demand by the butcher and by stock buyers in Canada and the United States. It is an animal of early maturity and of excellent quality meat. It also fills out very well, the proportion of dead to live weight being very high, and there is consequently very little waste in the carcass. Black coat colour and the polled or hornless condition are characteristic of the breed, and while the animal appears to be smaller than other beef breeds, on account of its short legs, it actually is one of the heaviest breeds.

The **Galloway** breed arose in the south-western part of Scotland, and is probably one of the oldest of our modern breeds. So ancient, indeed, is its ancestry that no trace can be found of the breeds which went to its formation. The Galloway is in many respects the grandest and most impressive looking of British breeds. It is black and polled, but differs from the Aberdeen-Angus in that the bones are heavier, the hair longer, and the poll not so pointed. It is a noted beef breed, the milk yield being deficient. The cross-bred animal, known as the "blue-grey," obtained by mating a white Shorthorn bull with a Galloway cow, is celebrated as an excellent butcher's animal.

**Sheep.**—There are several ways of classifying sheep, but probably that of (*a*) Longwools, (*b*) Shortwools, and (*c*) Mountain breeds is as convenient as any other.

**Longwool** breeds are distinguished by their large size, long wool, heavy fleece, absence of horns, and the white colour of face and shanks. They include the following breeds: British Leicester, Border Leicester, Lincoln, Cotswold, Romney Marsh, South Devon, Devon Longwool, Wensleydale, and Roscommon.

Of the **Shortwools,** true Shortwools are represented in the Merino, which is characterised by a firm, closely packed fine white wool, rather giving the appearance of a cauliflower. The breed is white in body colour, and the skin in some strains is much wrinkled in the neck region (Fig. 38).

The Down breeds, which have all been influenced more or less by English Southdown blood, are hornless, dark faced, and dark legged. The wool is short and fine and of medium weight. The Shortwool breeds include the following so-called "Down Breeds," namely, the Southdown, Shropshire, Suffolk, Oxford Down, Hampshire Down, Dorset Down, and in addition, include the Dorset Horn and Tyeland breeds of Great Britain, the Merino breed of America, and the Rambouillet breed of France.

The **Mountain** breeds are characterised by their hardiness and rather small size. They are very active and can thrive on poor food. The wool is coarse in most of the constituent breeds. In their natural surroundings, which are hilly or mountainous regions, they are slow in reaching maturity, but if brought down to the lowlands they thrive more quickly.

They include the Scotch Blackface, Cheviot, Lonk, Derbyshire, Gritstone, Rough Fell, Swaledale, Limestone, Penistone, Herdwick, Welsh Mountain, Exmoor Horn, and Dartmoor.

In such areas of the world as Australia, New Zealand, and Argentina, the earliest object of sheep farming was the production of fine wool, and for this purpose the Merino was far and away the most suitable breed. The perfection of refrigeration and cold storage methods, however, so enlarged the market for mutton that the carcass became of greater importance than the fleece. The big fat sheep, half-bred or three-quarter-bred Lincolns, or similar breeds, have gradually tended to supplant the small and lean, fine wool breeds. There has been as a result a disturbance of the wool market in that a scarcity of fine wool and a superabundance of coarse wool has come about. In Australia, where the droughts make it impossible always to fatten sheep for the market, this change from fine wool breeds to carcass breeds has been less pronounced. In Europe, except for Great Britain, the development of sheep farming in these newer countries has caused a general decline in the sheep-rearing industry.

An interesting development of the possibility of producing a breed which whilst being a good mutton producer will also produce fine fleece, is the Corriedale breed, produced by the New Zealand breeder Games Little, by crossing a Lincoln ram with a Merino ewe, and carefully selecting and inbreeding the succeeding progeny. There are now more than a score of registered flocks of this breed.

**Pigs.**—The prolificacy of the pig, its rapidity of growth, and the catholicity of its tastes as regards food, make it the most important and the most easily reared of meat-producing animals; but the requirements of the pig for food of a high protein content, since it is not a grazing animal, limits the distribution of the hog-rearing industries to areas where such food is easily and cheaply obtainable; areas, for example, where potatoes or cereals are produced, such as Ireland, Belgium, Holland, Germany, Denmark, the corn belt of North America; or to areas where natural food is available, such as the forests of Servia or South-western Germany or Spain and Portugal.

The type of animal required varies according to locality. On the whole, in North-western Europe the "bacon" type of pig is bred, that is to say, a long-bodied animal with lean back and thick belly, in whose flesh the muscle and fat occur alternately in streaks (Fig. 41).

In North America the so-called "lard hog" is bred, an animal useless for bacon production but admirable for meat or for lard. The lard hog is a natural consequence of a plentiful cereal supply in the form of corn. The bacon pig of the barley-growing regions of Canada and Europe is a natural consequence of the cost of cereals, since the swine breeders feed their animals as much as possible on grasses and clover, which produce more lean meat than does a corn diet.

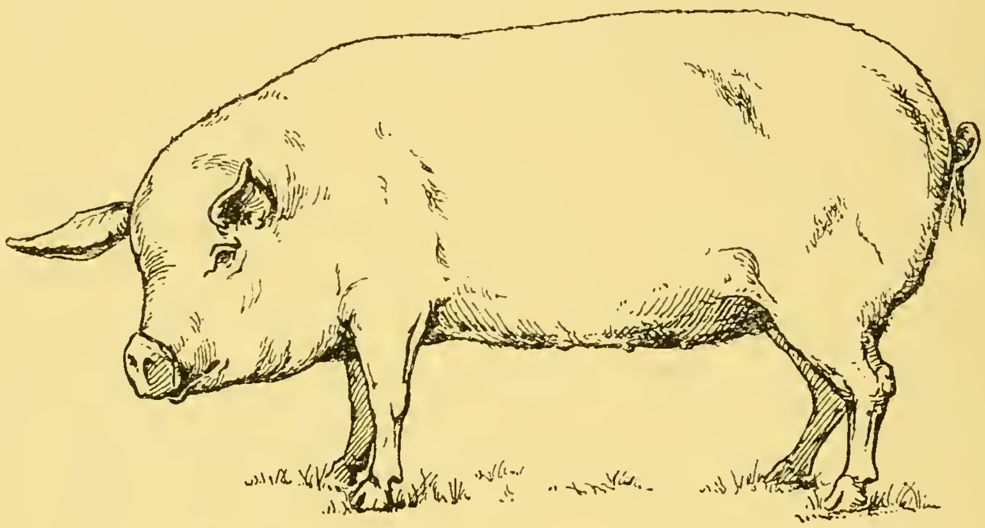


Fig. 41.—The Bacon Pig.

Of the enormous varieties of domestic pig, the really important commercial breeds are those derived or cross bred from the west European and, in particular, from the British breeds. These are divided into (*a*) White breeds, comprising the Large, Small, and Middle White or Yorkshires, the Curly-coated Lincoln, the Cumberland, Old Glamorgan, and the Large White Ulster; and (*b*) into Dark breeds, comprising the Large Black, Berkshire, Tamworth; (*c*) the Belted breeds, such as the Essex, Wessex, and Saddleback; and (*d*) the Spotted breeds, comprising the Gloucester varieties.

**Poultry.**—The various breeds of poultry are usually classified, according to their economic use, into:—

(*a*) Laying or non-sitting breeds.
(*b*) General purpose breeds.
(*c*) Table breeds.
(*d*) Ornamental breeds.

The laying breeds include the medium-sized and small

birds with a strong inclination towards egg production ; they are naturally active and seldom sit on their eggs, thus requiring exercise if they are to do well. As a rule they are quickly maturing birds, but their flesh is inferior for table purposes.

They comprise the following breeds : namely, the Ancona, Andalusian, Compine, Hamburg, Hendon, Leghorn, Minorca, and Redcap.

General purpose breeds, as the name implies, occupy an intermediate position between laying breeds and table birds, and include most of the various neglected, semi-wild breeds of backward countries. In Europe and America they include the La Bresse, Faverolles, Longshin, Orpington, Plymouth Rock, Rhode Island Red, Wyandotte, Sussex, and Australorp breeds.

The table breeds are valuable chiefly for their flesh. They are poor layers, slow in movement, with a tendency to put on flesh. They include the Dorking, Couçon de Malines, Game, and Indian Game breeds.

Ornamental breeds comprise particularly strains of the Bantam, Brahma, Cochin, and Silky breeds.

A good practical guide as to the category in which to place a particular fowl can be obtained by regarding the bird from the side and drawing an imaginary line from the front of the neck to the thigh. If the greater part of the body is found to lie behind this line, it is an indication of good laying qualities ; should the greater part fall in front of this line, the fowl will be found to be a table bird. If the body is apparently evenly balanced on each side of the line, the bird will be a general purpose or utility fowl, since both the laying and the flesh-forming qualities are equally developed.

## CHAPTER XXIV

## LIVESTOCK BREEDING

Speaking generally, the livestock breeder can choose between three lines of policy in order to obtain animals which show the particular qualities he desires; he may either go in for **inbreeding, outbreeding,** or **genotype selection.**

Inbreeding methods are based upon the occurrence of animals which possess to an unusual degree the power of stamping their characters upon the offspring, this impressive ability being termed "prepotency."

The principle adopted is that of selecting a foundation stock of rigidly selected animals, and, from this stock, to breed the resulting herd, no outside blood being admitted. Inbreeding may be carried to such length that an animal is mated to his own dam or sister.

Inbreeding was the method used by Bakewell, the founder of the Longhorn breed of cattle, a breed which, during the eighteenth century and the first ten years of the nineteenth was the most widely distributed and valuable British breed of cattle. He used inbreeding methods also to produce his famous Leicester breed of sheep. Bakewell started his Longhorn breeding at Dishley, in Leicestershire, about 1750, by obtaining the two best Longhorn heifers he could obtain. From these two, and a famous bull, "Twopenny," derived from one of these, he built up his famous Dishley herd. His breed became anxiously sought after, and eventually the Longhorn, from a large, lean, big-boned, slowly maturing animal local to North-western and Midland England, became the chief beef animal all over the country, until, owing to the weakened constitution and lessened milk capacity that inbreeding had brought about, it was ousted from popularity by the modern Shorthorn breed.

The methods of the first eighteenth century improvers of the old English Shorthorn cattle—the Collings of Darlington—were modelled upon those of Bakewell, and consisted in principle of the rigorous selection of a foundation stock and close in-and-in breeding of these selected animals. The breed of Shorthorn cattle they produced became known as the Durham or Tees-

water breed, and is still known under the name of Durham on the Continent and in America. The Shorthorn, before improvement, was a bulky animal, but although larger than the improved breed, weighed really less, since its body was less round and deep. As in the case of the Longhorn, improvement was made at the expense of constitution and milk production. Two notable successors of the brothers Colling were the Booths and Bates, both Yorkshire families of stock-breeders who, from animals procured from Collings, founded noted strains of the breed; similar methods were followed by Cruickshank in Scotland in producing the Cruickshank strain.

Although there is a popular belief that inbreeding results in decreased fertility and loss of stamina, the scientific evidence does not bear this out. The method in itself does not result in weakened constitution, but just as the good qualities of particular animals may be intensified in offspring whose parents are blood relations, so defective characters occurring in these parents may be intensified also. In a private herd subject to rigorous selection there is nothing harmful in the system of inbreeding. In the absence of such selection, however, a larger and larger proportion of animals will show sterility and lack of stamina.

A later development of inbreeding is **line-breeding,** that is to say the breeding from animals within the same line of descent but not immediately related.

Line-breeding has undoubtedly given good results in the improvement of most breeds. The desirable result of inbreeding, namely, the fixity of type, can be attained just as surely, although more slowly, by this less drastic method, and if line-breeding is accompanied by systematic and drastic weeding out of defectives, the proportion of such misfits that appear will in time be considerably fewer than will occur under a system of intensive inbreeding.

Out of the system of inbreeding has arisen the belief in **pedigree breeding,** that is to say, of selecting breeding animals partly on their own merits, partly upon the merits of their ancestors. From this has arisen the practice of keeping stud books and herd books in the different breeds of horses, cattle, sheep, and pigs. Thus, in Great Britain, no Shorthorn bull can be registered in Coates' Shorthorn Herd Book unless it has five crosses of Shorthorn blood, no cow unless it has four crosses. In the North American Shorthorn Herd Book, no animal can be registered unless its pedigree is recorded in Coates' Herd Book. No animal can be registered in the

Argentine Shorthorn Herd Book unless its pedigree can be traced in unbroken succession of named dams and registered sires to a named dam born in or before 1850, or to a named sire born in or before 1845. In Great Britain, unless a Thoroughbred horse can trace back in the female line to one of the original mares in the first volume of the Stud Book, it is impossible to get it entered in the Stud Book of to-day.

Obviously the defects of such a system are that breeders are led to neglect individual merit in a non-pedigree animal. An inferior animal with an irreproachable pedigree will not make a good breeder, since its inferiority is due to the loss of certain characters upon which the excellence of the breed is based, and it will only produce animals similarly lacking the desirable characters. Where the presence or absence of the desired characters can be indicated by some rigid test, as is afforded for the Thoroughbred horse or the American trotter by the practice of public racing, the danger of inferior animals propagating their like is of course minimised.

The converse method to that of inbreeding is that termed **outbreeding,** in which system care is taken to avoid mating animals which are related to one another. While this method is free from the disadvantages attendant upon inbreeding methods, its defect is that it leads to lack of uniformity in the herd.

The system of outbreeding is closely related to the earliest method of breeding, **mass selection,** or **phenotype selection,** the principle of which is to breed from the best individuals of each generation. Mass selection thus stakes everything upon individual merit. Now the outward appearance of an animal is not necessarily an indication of inward qualities.

Such characteristics as vigorous constitution, exceptional milk or egg-production ability and so forth, are not always correlated with external characters. Further, such qualities are not necessarily handed down directly to the children. Exceptionally tall human beings, for example, do not necessarily produce tall children, but more usually produce children whose height is nearer the average height for the race.

Outbreeding and mass selection methods, however, are capable of successful results if the individuals used as foundation stock have already shown their capacity to produce offspring possessing the desired quality. Thus, for example, in an endeavour to produce a herd of cows with high milking capacity, the ordinary method of outbreeding would be to employ a bull whose mother had been a noted milk producer. Such a

method might or might not result in the production of cattle of high milk-producing capacity, but would be in any case less successful than the employment of a bull which had been known already to have produced, say, half a dozen daughters of high milk production. The use of parents whose ability to produce good stock has been tested, may be termed **genotype selection.** It is of course a method only applicable to the selection of male animals, since the testing of a female animal on the basis of the quality of half a dozen of her daughters would take too long. With quickly maturing animals, or with animals which may produce six to twelve young at a time, such as hogs or poultry, however, it is possible to test the breeding capacity of either sex of the animals selected as foundation stock.

The application of Mendelian methods to genotype selection may, however, in the future make this method of breeding the only scientific one. At present, however, there is very little Mendelian data available concerning the inheritance of animal qualities.

The discoveries of Mendel, the Austrian monk, were of course made with plants, and since his time a great deal of similar work has been done with regard to the inheritable characters of plants, whereas comparatively little is known about the way the characteristics of animals are inherited. Coat colour of animals, however, seems to behave according to the Mendelian laws. Thus, if black Aberdeen-Angus cattle be crossed with red Aberdeen-Angus cattle, the offspring are all black. If these black offspring be crossed with one another or with similarly produced cattle, the resulting generation would be 75 per cent. black and 25 per cent. red. The red would breed always red cattle. Of the blacks, 25 per cent. would always produce blacks; the remaining 50 per cent. would produce again blacks and reds.

According to the Mendelian view, the black of the original parent is a characteristic produced by the presence in the tissue cells of a double dose of a certain factor; let us call it *B*. The complete absence of this factor is the cause of the red coloration of the other parent. The germ cells—spermatozoa or ova—of the black parent will each contain a single dose of *B*. The germ cells of the red parent will not contain *B*.

Now each individual of the first generation is the product of the union of a germ cell from the black parent with one from the red parent. Thus all the first generation will contain germ cells with only a single dose of *B*., whose presence, however, is sufficient to ensure that this generation is black in colour.

The germ cells of this first generation, however, will be of two sorts, some containing a single dose of *B.*, others not containing *B.* at all. When this first generation is hybridised, therefore, some individuals will contain a double dose of *B.* in their tissue cells and will be capable of producing black cattle; they are **pure dominants,** to use Mendel's term. Others will not contain any *B.* at all in their tissue cells, and will produce always red cattle; they are **pure recessives.** The remainder will have tissue cells with a single dose of *B.* and, although themselves black, their offspring will again be a mixture of 75 per cent. black to 25 per cent. red.

The two characters black and red colour, in this case, form a pair of **contrasted characters** or **allelomorphs.** The hybrid generation, which when interbred produces the mixture of red and black, again is said to be composed of **impure dominants.** The term **heterozygote,** however, is preferable. Certainly in this case the hybrid resembles superficially the dominant parent, but in other cases the hybrid does not resemble either parent, or may be exactly intermediate between both parents. If the term heterozygote be used, the pure dominant or pure recessive should be referred to as **homozygote.**

The condition in cattle of hornlessness, generally termed the "polled condition," again forms with the horned condition a pair of contrasting characters.

Thus, if an Aberdeen-Angus animal, which is black and polled, be crossed with an Hereford, which is of red body colour with a characteristic white face, and is horned, the hybrids will be found to be white faced with black body colour, and without horns. That is to say, the white face of the Hereford and the black coat and polled condition of the Aberdeen-Angus are dominant characters, whilst the plain coloured face of the Aberdeen-Angus and the red body colour and long horns of the Hereford are recessive characters.

If animals of this first generation type are interbred, the resulting offspring fall into eight groups according to their characteristics. These groups, together with the numerical proportions of the groups to one another, are as follows :—

| (1) White faced | (2) White faced | (3) White faced | (4) Plain faced | (5) White faced | (6) Plain faced | (7) Plain faced | (8) Plain faced |
|---|---|---|---|---|---|---|---|
| Black | Black | Red | Black | Red | Black | Red | Red |
| Polled | Horned | Polled | Polled | Horned | Horned | Polled | Horned |
| 27 | 9 | 9 | 9 | 3 | 3 | 3 | 1 |

The cattle in group (4) are like the Aberdeen-Angus; those in group (5) resemble the Hereford. Group (1) contains all the dominant characters; groups (2), (3), and (4) contain two dominants and one recessive; groups (5), (6), and (7) contain one dominant and two recessives; and group (8) contains all the recessive characters.

The limitation of our knowledge concerning the inheritance of Mendelian characters of animals is due chiefly to the expense and time required for such experiments. In the breeding of plants, many thousands of varieties may be bred quickly at little expense. On the other hand, the breeding of farm livestock is a comparatively long process, owing to the time it takes for each generation to reach maturity. More serious than this is the great expense entailed in breeding even a few animals where the offspring, though possibly invaluable from the point of view of the geneticist, do not possess the commercial qualities which determine saleable value.

The following data, however, are available :—

Chestnut coat colour in horses is homozygote. It is recessive to bay and brown colours.

Grey colour in horses is dominant to dun, bay, black, and chestnut.

Trotting in horses is dominant to pacing. In trotting, the near foreleg of course moves with the off hind leg, whereas in pacing the two legs of the same side are moved together.

In cattle, black coat colour is dominant to red. In Shorthorns, red is apparently homozygous and so is white. The hybrid generation of a red and white cross is a blend of red and white and is termed red roan. The hybrid of a black and white cross is a blue roan or blue-grey, such as is the Black Galloway and white Shorthorn cross.

In Sheep, black wool colour is homozygous and recessive to white.

The horned condition in sheep curiously enough is dominant to hornlessness in males but recessive in females. Thus, if a horned breed be crossed with a hornless breed, the hybrid generation is composed of horned rams and hornless ewes. When this generation is interbred, males occur in the ratio of three horned to one hornless, and females occur in the ratio of one horned to three hornless.

In hogs, white coat colour is dominant to coloured coat, but spotted individuals may occur in the cross.

When breeds are crossed together, generally for some commercial purpose such as beef, milk, or wool production, the

method is called **cross-breeding.** The idea in cross-breeding is to combine as far as possible the best points of both breeds. The well-known "blue-greys," the cross between the Black Galloway cow and the White Shorthorn bull, provide a classic example. This cross may also be made between the Aberdeen-Angus breed and White Shorthorns. In fact, such was the popularity of the blue-greys, that in the early nineteenth century the Aberdeen-Angus as a breed nearly faced extinction. The blue-grey is noted for its early maturity and superior quality of beef, and is always in demand by butchers.

Cross-breeding is a system of breeding which does not meet with approval on all sides. There is a tendency to neglect the breeding of the pure bred stocks, as happened in the case of the Aberdeen-Angus, and there is a temptation to breed from the exceptionally fine animals which are sometimes produced by the cross. Both of these practices are unsound, since cross-breeding has its basis in the excellence of the pure bred stocks: and breeding from cross-breds is bad, in that it speedily leads to loss of the superiority and uniformity of the original cross-breds.

The crossing of different but related species of domestic animal is termed **hybridisation.**

The most important example of hybridisation is the mule, or cross between a male donkey and a female horse. Both sexes of the hybrid are sterile, at any rate in the very great majority of cases. It is also possible to obtain a cross between zebra and horse or ass, the product being termed a *zebrule.* Such hybrids are undoubtedly stronger and more vigorous than either parent, and are very often more resistant to disease.

Thus, the Texas cattle fever of the United States, peculiarly fatal to imported Herefords and Shorthorn cattle, rarely attacks zebu cattle owing apparently to some quality of the zebu's skin that repels the Acarid host of the fever organism. A Zebu-Hereford cross apparently inherits this power of disease resistance whilst inheriting the build and beef qualities of the Hereford parent, and further, is fertile for both sexes, a somewhat unusual character in hybrids between species of the ox. Usually in crosses between such species the female is fertile and the male hybrid sterile.

In the case of the cattalo or ox-bison cross, mentioned in a previous chapter, the hybrids are intermediate in character between the parents, but superior to either in strength and size. The male hybrid is sterile, but the females are fertile and can

be crossed with bison or ox, the progeny again being intermediate between its parents in characters.

Bound up with this practice of cross-breeding and hybridisation is the question of **telegony,** the rooted belief of very many practical animal breeders in the influence of a particular male animal to stamp his characteristics not only upon his own offspring by a particular female, but upon the offspring of that female and other succeeding males. The prevalence of this belief among stock-breeders is evident in the rules of entry into many flock books. Breeding ewes cannot, for example, be registered in certain breeds if they have been crossed with rams of other breeds.

The classic example of telegony, of course, is that of Lord Morton's mare, a chestnut Arab which was mated to a male quagga and produced a hybrid of evident cross-bred character. The mare was subsequently mated to a black Arabian stallion and bore a filly, and, a year after this, a colt. The filly and the colt were very decidedly, as regards body structure, of the Arab breed, but in the colour and hair of the mane they resembled the quagga ; both had dark stripes across the withers and neighbouring parts of the neck, and dark bars across the back of the legs. The bars on the legs both in the hybrid and the foals were more strongly marked than on the legs of the quagga, and the stripes on the withers of the hybrid were fewer and less apparent than in the foals.

This case, however, has not been able to withstand the fire of later scientific criticism.

Striping in the horse, especially in Oriental breeds, is not uncommon. The original yellow dun horse of the forest type had, it is believed, a band down the back and bars like a zebra across the legs, with faint striping on neck and withers. The striping of Lord Morton's foals may therefore have been a reversion to some ancestral type.

Cossar Ewart of the University of Edinburgh carried out some classic experiments which in their results oppose this belief in telegony. He crossed the Burchell zebra stallion "Matopa" to a chestnut polo pony. The offspring were twin hybrids. The next year the pony was mated with a light chestnut thoroughbred stallion, and one foal resulted. Again, she was mated with "Matopa" and had a third hybrid foal. Later, mated with a dark chestnut thoroughbred, she produced another foal. The three hybrids were strongly striped, whereas the two foals in no way resembled the hybrids, but were chestnut in colour without the slightest trace of striping. Similar

experiments by other investigators also support the view that there is no scientific basis for a belief in telegony.

It may be added there is similarly no scientific support for the breeders' belief in *maternal impression*, and that the Scotsman M'Combie, the founder of the modern Aberdeen-Angus, had no necessity to build his famous high black fence around his fields to prevent his black Aberdeen-Angus cows dropping anything but black calves.

# PART III

# ANIMAL INDUSTRIES

## CHAPTER XXV

### BEE-KEEPING

The value of the three principal insect products useful to man, namely, honey, silk, and lac, to a civilised community is still of very great importance despite the competition of sugar, of artificial silk, and of cellulose varnishes.

Quite apart from the commercial value of bee products, apiculture is a branch of agriculture almost essential to a fruit-growing area, since bees are the chief insect agents in the cross-fertilisation of many varieties of fruit trees, and experience has proved that there is a definite correlation between the yield of fruits of certain kinds, particularly apples and plums, and the abundance of bees in the area.

In every country where bee-keeping is practised, the insect utilised is some race or other of *Apis mellifica*. This species has been made use of from time immemorial, and deserves perhaps as well as many other animals the term "domesticated." The only other species of *Apis* are three Indian representatives. Of these, *Apis dorsata*, the Rock Bee, is a large bee, whose worker is as big in size as the queen of *Apis mellifica*. Each colony builds a huge comb on the face of a cliff or on a branch of a big tree, the comb being as large as five feet across. The bees are very ferocious and will not tolerate domestication in a hive. Their combs are extensively robbed by the wild hill tribes, not only for the honey, but for the large quantity of wax.

*Apis florea*, the Little Bee, builds a single comb as big as a man's hand in bushes or under the eaves of buildings. It is not prone to sting, but will not tolerate domestication, which in any case would hardly be worth the small quantity of honey to be obtained.

*Apis indica*, the Indian Bee, is probably a sub-species of

*Apis mellifica*, and occurs both wild and semi-domesticated throughout India. The colony builds several parallel combs generally in semi-enclosed places such as hollow trees or rock crevices. The yield of honey is nothing like so great as that produced by European races of *Apis mellifica*.

In the tropics of the Old and New Worlds, wild bees of the genera *Melipona* and *Trigona*, minute bees characterised by vestigial stings, make large nests in hollow trees, or in holes in rocks and walls. The nest often possesses a projecting entrance like a funnel, which can be closed at night by cerumen, a mixture of wax and earth or resin. The honey of these so-called "mosquito bees" is sought for and much used by natives of their area of distribution.

*Apis mellifica* itself comprises a number of races, each of local origin. Thus there is the North European Black Bee, with its grey Carniolan variety, from Austrian Tyrol; the golden banded Italian race, the Caucasian race, the Tunisian, Syrian, Cyprian, and so on.

The most favoured races in Great Britain and North America are Black and Italian and Black-Italian hybrids.

**The Housing of Bees.**—A healthy colony of *Apis mellifica* will comprise 30,000 - 40,000 worker bees, a single queen, and a varying number of male or drone bees. In a state of nature, such a colony will suspend its vertical combs of cells from a tree branch or a rock, relying upon the overhang of tree or rock for protection from the elements. Under the conditions of Northern Europe or America, such a wild colony would be unable to tolerate winter conditions unless it had been so fortunate as to occupy a hollow tree or a rock crevice.

The old system of bee-keeping, and one, unfortunately, still too prevalent, is to house the bees in a box or a skep, that is to say, a straw structure like an inverted basket. In such a box hive or skep the vertically suspended combs become cemented to the sides of the house, and the colony has to be killed before any honey can be obtained; periodical examination of the insects, or artificial feeding, is impossible.

The great advance in the technique of modern bee-keeping dates from the introduction of the **Frame Hive,** devised by Langstroth in 1857. The Frame Hive (Fig. 42) consists in principle of a square box made up of a number of horizontal stories.

The box rests upon a platform about nine inches from the ground, and the platform projects in front of one side of the box base so as to form an **alighting board**; at the junction of

alighting board and box a horizontal slit provides an entrance into the hive.

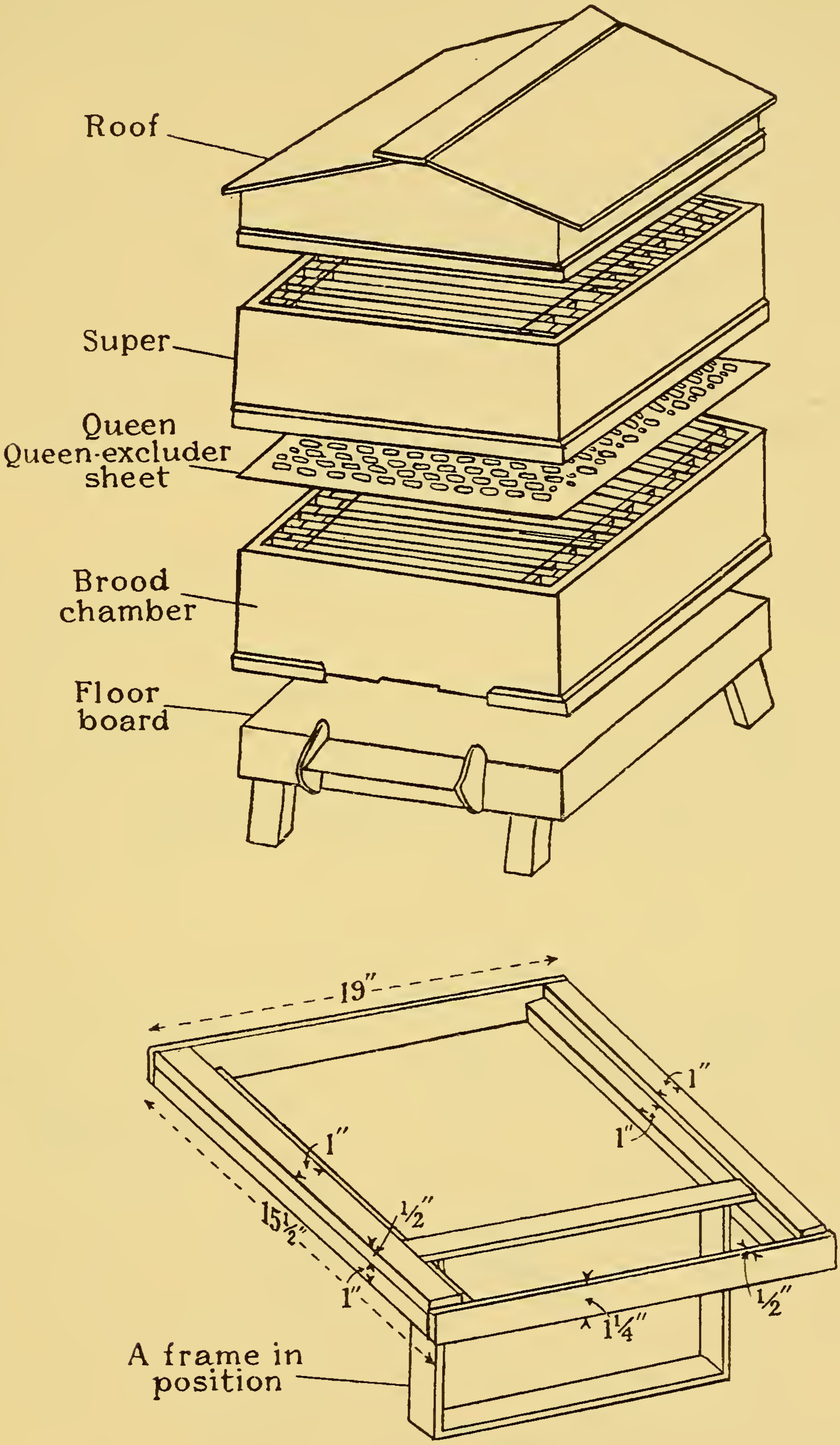



FIG. 42.—The Frame Hive. (After Ghosh.)

The lowermost story is termed the **brood chamber**; the remaining stories are termed **supers,** and will vary in number according to the size of the colony. Commencing with the alighting board, a brood chamber, and a roof, the hive can be

increased by the interpolation of supers to keep pace with the growth of the colony throughout the summer. The best type of frame hive is made with a double wall, there being an outer shell, which is just a square box, within which there is the tower of supers, separated from the outer shell by a space of one or two inches.

In each super a number of rectangular frames are fitted. Each frame consists of a sheet of wax, on each side of which ready-made cell bases have been stamped, enclosed in a rectangular frame of thin strip wood one and three-eighth inches in width. The frames are arranged parallel to one another and vertically, not touching each other nor touching the sides of the super, nor the top nor base of the adjoining supers. The frames are just sufficiently clear of one another to allow the bees to crawl over the waxen faces. A super will contain ten such frames.

In such a hive the frames are easily examined or removed. The roof of the hive can be removed, the bees driven down from the uppermost super by a few puffs of smoke from a bellows containing smouldering tinder, and any individual frame can be removed and examined, or can be replaced by a fresh frame. A super of frames can be removed bodily and the honey in the combs readily extracted, without the necessity of killing a single bee. Furthermore, in a frame hive, winter feeding of the colony is possible, cakes of candy being placed periodically on the top of the uppermost super.

A simple but ingenious form of hive for use in tropical countries where ground hives are a disadvantage, is the **Khartoum Hive,** designed by Mr H. H. King for the cultivation of *Apis mellifica* subsp. *unicolor* in the Southern Sudan. It is an improved type of native hollow palm-log hive, but is woven of basketwork, dom palm leaves being utilised, and, as shown in Fig. 43, consists of two sections, one to act as a brood chamber, the other to act as a honey chamber. The honey chamber and its contained combs can thus be removed without the necessity for destroying the colony and the brood combs. Further, the hive can be suspended in a tree and so protected from honey-loving ground animals.

**Problems of Apiculture.**—The most important general problems of the modern apiculturist concern :—

(1) The control of swarming.

(2) The prevention of disease and parasites.

(3) The care of bees in winter.

Swarming is the natural corollary of the increase in abund-

ance of individuals in an already overcrowded hive, and a swarm usually consists of a number of workers led by the old queen who has become superseded in the old hive by a new queen reared by the colony.

Such a swarm may settle on the bough of a bush or tree

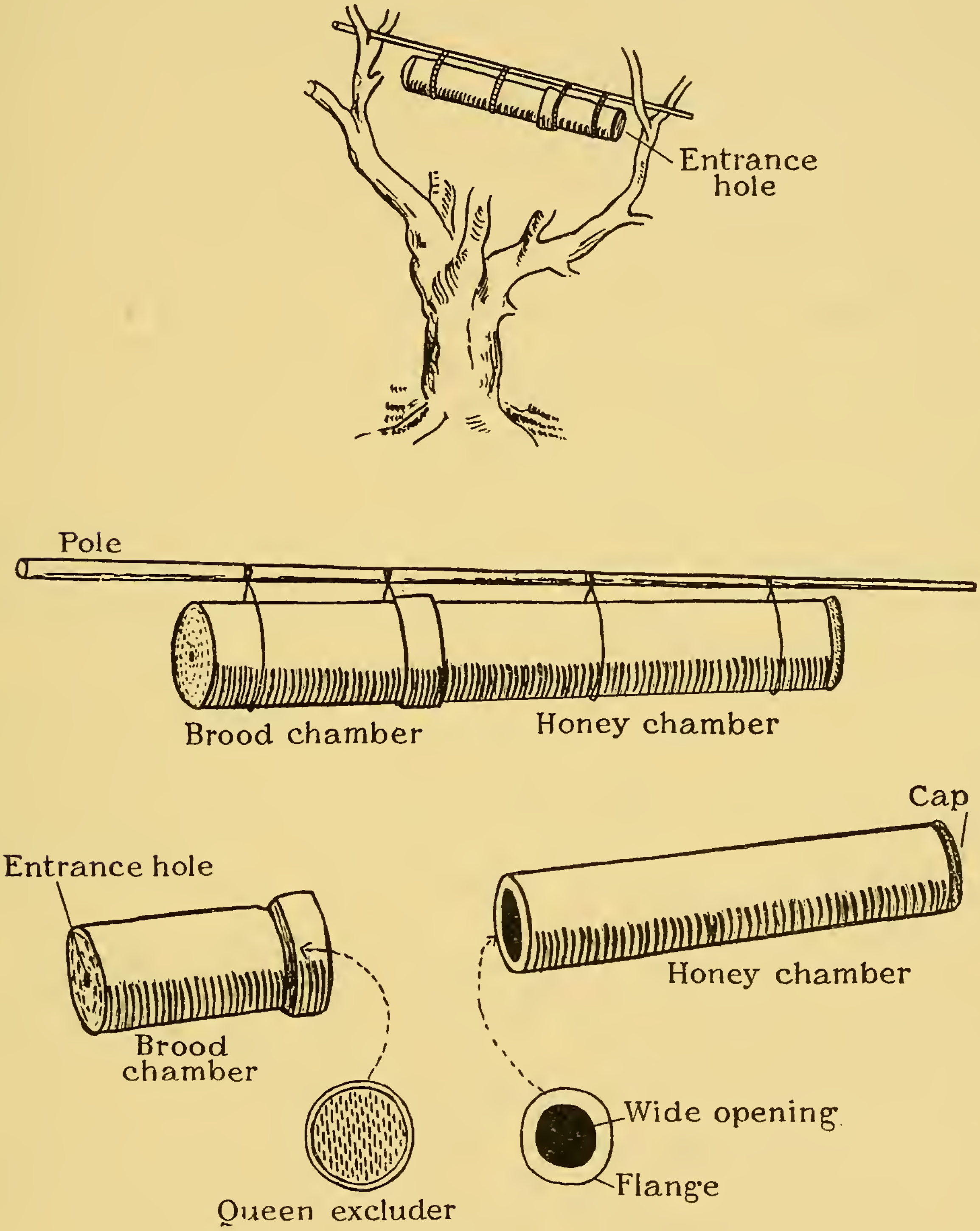



FIG. 43.—The Sudan Hive. (After King.)

near at hand, and can be readily shaken into a skep and transferred to an empty hive ; but very often the swarm travels some distance across country and may be irrecoverable. The tendency of a swarm to travel can be overcome to some extent by clipping the forewing of one side of the queen with a pair of fine scissors, early in the spring, so that if swarming does

occur, the queen cannot fly and the swarm will not leave the vicinity of the hive.

The chief causes of swarming are an overcrowded condition of the hive and an inability of the queen to find empty cells in which to lay eggs.

In a hive of bees there are, so to speak, two categories of working bees: there is a stay at home category, or **nurses**—usually worker bees of less than a month old—queen attendants, guards, drones, and ventilators—that is to say, old workers whose duty it is to create a circulation of air through the hive by continuous wing movement; there is a category of outside workers, or **foragers,** who bring in the supplies of nectar and pollen from the flowers. All these bees require their share of honey before any can be taken by the bee-keeper. The amount of honey used by a colony simply to maintain its existence during a year is large, probably at least 400 lbs. Therefore what the bee-keeper can appropriate is the surplus beyond this 400 lbs., a surplus which will depend very largely upon the weather conditions during the period of summer when blossoms are secreting nectar freely, a period usually termed the **honey flow,** and will depend upon the number of field workers available after the duties inside the hive have been allowed for.

In an average season the amount of surplus honey per hive should average 50 lbs. Now the bee-keeper cannot influence weather conditions during the honey flow, but he can influence, to some extent, the margin of field workers over home workers by restricting the amount of brood that is being reared, since brood rearing absorbs a very great deal of labour within the hive.

A queen honey-bee is capable of laying 3,000 eggs per day throughout the honey gathering season, and the resulting larvæ, unlike those of other bees, are fed individually by nurse bees at frequent intervals throughout the period of larval life, a period of eight days. Such feeding involves an average of 1,300 visits per larva per day. Thus, brood rearing involves heavy cost in labour and in food, which is, of course, honey and pollen.

The usual policy in apiculture, therefore, is to encourage brood rearing in early spring, to replace the losses due to winter mortality; to discourage brood rearing during early summer, the period of the honey flow; to encourage brood rearing in late summer so as to establish a strong colony before the winter arrives.

Brood rearing may be discouraged by shutting off the

lowermost one or two supers from the upper supers by a **queen excluder,** a perforated zinc plate whose openings permit worker bees to pass through to the storage cells above, but prevent the passage of the larger queen. Other methods are the removal of brood comb and imprisonment of the queen in a wire cage. Thus during the summer the queen's opportunity to lay eggs is restricted, the hive becomes overcrowded from the progeny of the spring broods, the hive temperature, in sympathy with the outer temperature, is high, and conditions conduce to swarm production. Unless the overcrowding is minimised by provision of extra supers, and unless a keen watch is kept upon the brood combs for the conspicuous projecting cells of future queens, and these cells removed, swarming is inevitable and a consequent loss of potential surplus honey will result.

**Bee Diseases.**—The diseases to which bees are subject may be divided into two groups, namely, diseases affecting the adult bees and diseases affecting the brood.

Of all these diseases, the two affecting the brood which are known respectively as **European Foul Brood** and **American Foul Brood,** are by far the most serious and a menace to apiculture everywhere.

Both diseases are bacterial in origin, American Foul Brood being probably caused by *Bacillus larvæ*, and European Foul Brood being probably caused by *Bacillus alvei* or *Bacillus pluton*, and both diseases are highly infectious, infection occurring via the alimentary canal through contamination of food with spores of the causative organisms. Infected larvæ usually become dark in colour, become semi-liquefied, and eventually dry up to what is termed a "scale."

**Sac Brood** is an infectious brood disease of bees caused by a filterable virus.

There are at present two methods for the treatment of a hive in which a brood disease occurs. These two methods are :—

(1) The removal of the adult bees to a new hive, and the disinfection of the frames of the infected hive by immersion for forty-eight hours in a mixture of 20 parts of formalin with 80 parts of water, or, preferably, of 90 per cent. of alcohol. The frames after disinfection are thoroughly dried and aired, and can then be placed in the new hives.

(2) The Alexander method, in which the queen is removed and the bees are left in the infected hive in a queenless condition for twenty-seven days, during which period the workers clean up the cells and polish them in readiness for the eggs of the new queen. A young Italian queen is then introduced. Weak

colonies must be strengthened or united with another colony before treatment.

The following table, as given by A. H. M'Cray and G. F. White of the United States Department of Agriculture, summarises the difference between these three important brood diseases :—

Table I.—*Differential Features in the Diagnosis of the Brood Diseases of Bees by Laboratory Methods.*

| | European Foul Brood. | American Foul Brood. | Sac Brood. |
|---|---|---|---|
| General appearance of brood | Brood irregular. Large amount of affected brood unsealed | Very irregular ; affected brood sealed, sunken and perforated caps present | Brood less irregular, perforated caps present, dark sunken caps not so pronounced as in American foul brood. |
| Proportion of affected brood | Varying number of young larvæ affected, usually many | Usually a large amount of brood affected | Small amount of brood affected. |
| Position within cell | Usually curled at bottom. Larvæ soft, with melting appearance | Extension along lower cell wall. Larvæ soon become a shapeless mass | Extension along lower cell wall. Head turned upward. Normal form maintained. |
| Age of the larvæ | Usually die before capping | Usually die after capping | Almost invariably die after capping. |
| Coloration . | Larvæ yellow, grey, and brown | Usually dark chocolate | Soon become dark brown to almost black. |
| Odour . . | Slight, inoffensive . . | Usually strong characteristic odour. More or less offensive | None. |
| Consistency . | Soft, rather friable . . | Viscid, can be "roped" out a distance of three or four inches | Contents watery and granular. Larvæ can be removed from cell without rupturing body wall. |
| Kind of brood affected | Often considerable amount of drone brood as well as worker brood | Any considerable amount of drone brood less likely to be seen | Greatest ravages among worker brood. |
| Scales . . | Usually small and lie at bottom of cell. Yellow, grey, or brown in colour. Sometimes a few larger, brown, rubber-like scales. All scales separate readily from cell wall | Extension along lower cell wall dark brown in colour. Surfaces somewhat smooth. Separate from cell with difficulty | Extension along lower cell wall. Dark in colour, often black. Somewhat roughened appearance. Separate readily from cell wall. |
| Microscopic findings | *Bacillus pluton* always. *Bacillus alvei* usually. *Streptococcus apis* sometimes. *Bacillus orpheus*, *Bacterium eurydice*, *Bacillus vulgatus*, and *Bacillus mesentericus*, occasionally | Usually only *Bacillus larvæ*. Occasionally *Bacillus vulgatus* and *Bacillus mesentericus* | Negative as a rule. |
| Cultures . . | Any of the above organisms except *Bacillus pluton* | Frequently negative. Never *Bacillus larvæ* on common media | Nearly always wholly negative. |

The most serious disease to which adult bees are subject is that peculiar form of wing paralysis accompanied by abdominal distension, by putty-like excreta, and by death, to which in Great Britain the name of Isle of Wight Disease used to be applied.

This term apparently has been applied to a combination

of symptoms characterising two separate diseases, namely, **Microsporidiosis,** a Protozoan disease caused by the presence of a Microsporidian Protozoan—*Nosema apis*—in the chyle stomach of infected bees, and the main cause of the "dry diarrhœa"; and **Acaridiosis,** caused by the presence of a mite—*Acarapis woodii*—in enormous numbers in the tracheæ of the thorax. The bee thus becomes semi-suffocated and incapable of flying, and its abdomen becomes distended owing to inability to defecate, as it normally does, whilst flying. Acaridiosis is apparently peculiar to Great Britain.

**Parasites and Predators.**—The principal animal enemy of hive bees is the Large Wax Moth (*Galleria mellonella*), a Pyralid moth, and its companion species, the Lesser Wax Moth (*Achroia grisella*). These moths creep into the hive at dusk and lay eggs on the combs, usually becoming stung to death before they emerge again. The caterpillars, which grow to the size of an inch, tunnel through the combs, and although essentially scavenging in habit, cause great destruction. The tunnelling habit, aided by a silken protective web, protects the caterpillars from the bees.

## CHAPTER XXVI

## SERICICULTURE AND LAC CULTURE

NATURAL silk, although produced by a variety of insects and spiders, is obtained on a commercial scale only from the cocoons of moths belonging to the families *Bombycidæ* and *Saturniidæ.*

The *Bombycidæ* includes the domesticated silk moth, *Bombyx mori*, and a number of other species characteristic of the Oriental region ; *Bombyx mori* is unknown in the wild state. The *Saturniidæ*, of which the only British species is the Emperor Moth *Saturnia pavonia*, includes a number of semi-domesticated and wild silk-producing genera, notably *Attacus*, *Antheræa*, *Philosamia*, and *Anaphe.*

The silk is formed in the body of the caterpillar as a fluid in the salivary glands, which open by two small apertures on the lower lip. The silk is poured out as a thick, gummy, transparent fluid, which rapidly hardens and dries, assuming then a yellow or brown tint. When used in cocoon building, the silk occurs as an outer layer, whose thread is not necessarily continuous, to fix the cocoon to some object, and as an inner layer, formed of practically one continuous thread wound regularly round and round and ending at some point inside the cocoon where the caterpillar finishes. From such a cocoon, the greater part of the silk can be reeled off in a continuous thread. The cocoon must first be heated, however, to kill the enclosed insect, which would otherwise injure the silken wall when biting its way out. In other *Saturniidæ*, however, the cocoon consists of distinct layers, composed of somewhat irregularly disposed threads, and the emerging moth merely pushes its way through the end of the cocoon. Such cocoons, if required to produce commercial silk, must be teased up and the tangled fibres spun by machinery.

There are thus two categories of silk, namely, **reeled silk** and **spun silk.**

The principal kinds of reeled silk are **Mulberry silk, Shantung silk, Japanese silk, Tasar silk, Muga silk.**

The principal kinds of spun silk are **Eri silk** and **Anaphe silk.**

**Mulberry Silk** is the product of *Bombyx mori*, originally a

native probably of Northern China, but now established as a domesticated insect throughout China, in Japan, India, Kashmir, Burma, Siam, Corea, Afghanistan, Persia, Central Asia, Armenia, Syria, Turkey, Egypt, Algeria, Greece, Italy, France, Spain, America, Australia; in every region of the world, in fact, where it has been possible to acclimatise the White Mulberry (*Morus alba*), the only food plant on which the insect will thrive.

The original race of *Bombyx mori* was probably *bivoltine*, that is to say, possessing two broods in the year, but domestication has produced a number of races or variations which differ considerably in the number of broods per year.

In countries where the summer is short and hot and the winter long, *univoltine* races have evolved; in countries where hot, damp conditions prevail, *multivoltine* races occur. The cocoons of univoltine races are much superior to those of multivoltine races. European and Japanese races are chiefly univoltine. Chinese and Indian races are chiefly multivoltine.

The general methods of rearing the caterpillars and of obtaining the silk are much the same in all the producing areas. The caterpillars are reared in round or oval trays of wicker-work on a bed of chopped mulberry leaves, to which fresh food is added at frequent intervals varying from nine times a day for the youngest caterpillars to five times a day for the oldest. The caterpillars moult at intervals of three or four days, and at that time take no food for twenty or thirty hours. They must be then left undisturbed.

The trays of caterpillars are kept on shelves under cover of a roofed building.

In a cool climate, such as that of Southern Europe, there are five caterpillar stages separated by moults. The approximate number of days of each stage, the amount of food, and the area required by the caterpillars which hatch from one ounce of eggs (30,000-35,000) are, according to Lefroy, as follows:—

| Stage. | Days. | Food in Lbs. | Area in Square Feet. | |
|---|---|---|---|---|
| | | | Univoltine. | Polyvoltine. |
| 1 | 5 | 4 | 1 | 1 |
| 2 | 4 | 12 | 5 | 9 |
| 3 | 6 | 40 | 10 | 30 |
| 4 | 7 | 112 | 20 | 100 |
| 5 | 10 | 700 | 40 | 200 |

When the worms are full fed they become restless and are transferred to a special tray in which they spin their cocoons, the process taking three days. Those cocoons which are required to produce moths for egg laying are picked out. The remainder are sterilised by baking or by exposure to sun heat.

The moths from unheated cocoons emerge, copulate, and lay eggs, which are received usually on paper, to which they stick. The parent female, after death, is pounded up with a little water and examined microscopically for the shining pèbrine bodies (*vide* Chapter XIX.), and if infected, that batch of eggs is rejected.

The eggs do not hatch, in the case of univoltine races, until after the lapse of ten months. They are kept, therefore, for six months in a refrigerator, then removed and gradually introduced to a temperature of 60°-70° F., at which they remain for thirty days before hatching.

One ounce of eggs will produce about 36 lbs. of dried cocoons, or about 30,000 cocoons, and the length of the thread from a cocoon averages 1,300 yds.

After the cocoons have been heated in an oven, or by sun heat, or by steam, they are soaked in warm water until the silk glue is softened. Several loose ends from several cocoons are then twisted together, and the combined thread is reeled off by a machine. The product is *raw silk*. The waste resulting from damaged cocoons, the irregularly spun and tangled outer layers, and the unreelable portion of the inner layer, constitutes *floss silk* after it has been teased and spun.

**Shantung Silk** is the product of the Saturniid *Antherœa pernyi*, the Chinese oak silkworm, a wild and semi-domesticated moth of China. As the name implies, the chief food is oak leaves, and the silk is of a pale buff colour. The caterpillar itself is also yellow. The cocoon is large, nearly two inches long, and firm.

**Japanese Silk,** or Green Silk, is the product of *Antherœa yami-mai*, a green caterpillar which also feeds on oak leaves. It is reared on a large scale in Japan and was introduced into Europe in 1861.

**Tasar Silk** and **Muga Silk** are the products respectively of the Indian silk moths *Antherœa paphia* and *Antherœa assami*, polyphagous forest-frequenting Saturniids of Northern India. Tasar silk varies in colour from yellow to greenish-brown, according to the particular race of *Antherœa paphia* which has produced it.

Muga silk is white or yellow, and is consumed locally in Bengal and Assam, where it is produced.

These moths cannot apparently be domesticated, the

caterpillars not thriving in captivity. Cocoons, therefore, are collected in the forests, the search involving considerable labour, although attempts are being made here and there to establish the insects in plantations of favourite food plants, as is done in China and Japan with the oak silkworms.

In Assam, however, the Muga silkworm, although fed on the trees, is carefully supervised and removed to the rearers' houses when ready to spin. The cocoons are killed by exposure to the sun, are boiled in an alkaline solution, and are then reeled by primitive hand methods. In European factories, however, cocoons of Antheræa species are usually teased or carded, and the products then spun by machinery.

**Eri Silk,** the chief variety of spun silk—a term which, unfortunately, also embraces the spun product of mulberry silk refuse—is also the product of an Indian Saturniid, *Philosamia ricini.* This insect is reared in Assam almost as readily as the mulberry silkworms can be reared, and very much in the same way. Although polyphagous in habit, it is reared in captivity on leaves of the castor-oil plant (*Ricinus communis*). The worms are, of course, much bigger than those of *Bombyx mori* and take up more room. When full fed, they are put into baskets with dried mango leaves. All the moths are allowed to emerge naturally from the cocoons, and the cocoons are then treated by crude, local methods. They are first turned inside out, in order to remove the cast pupal skin, either by hand or by the little Coryton machine introduced by the Agricultural Department of India. They are then soaked in 12 per cent. sodium carbonate solution, teased up by hand, and hand spun.

In West Africa, a Saturniid moth *Anaphe* is being experimented with as a possible source of spun silk. The species which are being experimented with are *Anaphe infracta*, *Anaphe ambrizzia*, and *Epanaphe moloneyi*. The larvæ are gregarious and pupate in large communal nests of silk attached to branches of trees. The larvæ are extraordinarily susceptible to extraneous interference, so that domestication on the lines of that practised with *Philosamia ricini* is apparently impracticable. There seems, however, a distinct possibility that in French West Africa, in Nigeria, and in Belgian Congo the collection of these silken nests as a source of spun silk will develop into a commercial proposition.

**Lac Culture.**—Shellac, the basis of most commercial varnishes and enamels, and a raw material in the manufacture of gramophone records, sealing wax, and a host of miscellaneous household articles, is the product of a Scale Insect, *Tachardia lacca*,

which is deliberately cultivated on various food plants in India, particularly in the Central Provinces. An inferior quality of shellac, containing a much greater percentage of wax, is obtained in Madagascar from another Coccid species, *Gascardia madagascarensis*, closely allied to the Indian lac insect.

The lac itself is a resinous substance exuded by the female insect and forming a protective covering around her, preventing her from moving from the particular spot on the plant upon which she settled as a larva.

A large proportion of the trees selected by *Tachardia* as food plants contain a gummy or resinous sap, and the colour and quality of the lac are influenced by the particular tree upon which the insect happens to settle. Thus the best lac is obtained from insects cultivated on the Kusumb (*Schleichera trijuga*); but since this tree does not grow well below an altitude of 2,000 ft., the insects are frequently cultivated on more widely distributed trees such as Ber (*Zizyphus jujuba*), Palas (*Butea frondosa*), Peepal (*Ficus religiosa*), Siris (*Albizzia lebbek*), and in Assam on the herbaceous plant *Cajanus indicus*.

On a tree infected with *Tachardia*, the twigs will appear to be covered with resinous globules adhering to the bark and so close together that it is difficult to see any unattacked areas of bark. Twigs from such a tree are referred to as **brood lac.**

The eggs are laid by the female beneath the resinous outer covering, and the newly hatched larvæ, which are scarlet in colour, emerge through a hole at the posterior edge of the scale and migrate to succulent unattacked parts of the plant. Having selected a suitable spot, each larva settles down, and if it happens to be a female, does not move again from that point. If a male, however, the insect will migrate again after a period of time dependent upon the particular brood. This swarming of newly emerged larvæ occurs twice a year, there being a hot weather brood and a cold weather brood.

Male insects appear about one month after the fixation of the larvæ, in the case of the hot weather brood, and are either winged or wingless. The males of the cold weather brood emerge about three and a half to five months after fixation and are wingless. The exudation of the lac commences soon after fixation of the larvæ, proceeds very slowly at first, but much more rapidly after fertilisation.

After the emergence of the young brood the parent females die rapidly, and all that is left is an almost black shrivelled skin lying in the central cavity of the lac encrustation.

It is important to note that the female ceases to feed three

weeks before the emergence of the larvæ, so that a twig carrying brood lac can be cut from the plant as long as a fortnight before the emergence of young larvæ, and sent to distant places by mail, without any harm being done to the females or developing eggs.

It is of course a matter of great importance to the cultivator that he should know the approximate dates of emergence of brood for his own particular locality.

The general principle of carrying on lac culture is the inoculation of suitable trees, generally prepared beforehand by pruning, by tying to them a number of twigs bearing brood lac. Branches of brood lac are cut from an infected tree about a fortnight before brood emergence is expected, are cut into short pieces of eight to eleven inches, and are then spread on bamboo racks in an airy place. About a fortnight after, when a few tiny deep red insects are seen crawling over the sticks, the sticks are taken to the trees already pruned and tied to their branches with some cheap fibre ; about five to twenty sticks are tied in each tree, according to the size and condition of the tree, and they are tied in such a way that their ends touch the branches. After the larvæ have ceased to emerge, a period of ten days to as long as four and a half weeks, the brood sticks are removed, brought home, and the resin scraped off with knives or twisted off with the hand. The scraped material is termed commercially **stick-lac.** This stick-lac should be washed as soon as possible from the red dye which it contains. After repeated washing and straining, the lac is like a coarse pale orange powder, and constitutes the **seed-lac** of commerce. This, when mixed with 2-3 per cent. of yellow orpiment to impart colour, and with 4-5 per cent. of pine resin to lower the melting point, is melted down and recooled into sheets of **commercial shellac.**

The lac dye, which was formerly more valuable than the lac itself, and was extensively used before the introduction of aniline dyes for the colouring of wool and leather and silk, is now of little commercial value and is used by Hindu women for colouring the soles of their feet, or is used as a manure, being rich in nitrogen.

The lac insect suffers considerably from the attacks of predaceous caterpillars of a small Noctuid moth, *Eublemma amabilis*, which eat both lac and the scale insect inside. A predaceous Tineid caterpillar, *Hypatina pulverea,* is even more abundant than *Eublemma*, and almost equally destructive.

Like other Scale Insects, *Tachardia* is also heavily parasitised by Chalcid and Braconid Hymenoptera.

## CHAPTER XXVII

## FRESH-WATER AND ESTUARINE FISHERIES

The term " fishing industry " is not necessarily to be restricted to methods of capturing food fishes, but is a term which covers various commercial methods of capturing or cultivating a large variety of aquatic invertebrate and vertebrate animals, destined either for human consumption or for other uses. The term can thus be applied to the procuring of precious corals, sponges, pearls, shellfish, cuttle fish, bêche-de-mer, fishes, seals, and whales.

The fishing industries can be divided into three categories :—

(1) Fresh-water and estuarine fisheries.

(2) Inshore or coastal fisheries.

(3) Offshore or bank fisheries.

The fresh-water and estuarine fishing industries, again, may be divided into three categories, namely :—

(1) Those concerned in the capture of the migratory phases of certain fishes.

(2) Those concerned in the breeding and rearing of food fishes in artificial fish-ponds or in lakes.

(3) Those concerned with the rearing of young fishes in hatcheries, for the restocking of streams and lakes with fishes intended either as food, or to provide sport for anglers.

A considerable number of fishes, probably the great majority, migrate when desirous of spawning to water of density less than that of the normal habitat. Such fishes are termed *anadromous*.

The degree of migration undertaken varies with different fishes. The salmon, for example, a deep sea fish, migrates from the seas right up to the shallow headwaters of European and western American rivers in order to copulate and to produce eggs, and the young salmon must therefore undergo a return migration to the sea. The sturgeon migrates from the seas to the lower reaches of rivers. The shad, a sort of herring, migrates merely from seas to estuaries. The herring migrates from offshore to inshore waters ; the pike, an exclusively fresh-water fish, migrates up stream to spawn.

On the other hand, a number of fishes are known to be *katadromous*, that is to say, to migrate to water of *greater* density than that of their normal habitat in order to spawn. Thus the fresh-water eel migrates, when four or five years old, from the upper reaches of rivers and streams, down-stream and to the great depths of an area of the Atlantic Ocean lying south-west of the Bermudas. The conger eel migrates from inshore waters to offshore waters. The plaice migrates from inshore waters to offshore waters, and so on.

There are many examples of fishing industries of considerable importance in which this habit of migration is taken advantage of, and fish are caught on a large scale in the river estuaries either as migrating adults or as returning young forms. The chief methods involved may be illustrated by reference to the capture of the following fishes, namely, the Pacific Salmon, the Sturgeon, and the Fresh-water Eel.

**The Salmon Fisheries.**—The family *Salmonidæ*, an ancient family of fishes, comprises a number of fishes of the salmon and trout type, not all of which are classed as migratory. The Atlantic Salmon (*Salmo salar*), the Pacific Steel-head Salmon (*Salmo gairdneri*), and the Pacific Sock-eye and Dog salmons (*Oncorhynchus*) are extremely anadromous, passing from the deep waters of the Atlantic or Pacific oceans to the head waters of west European rivers or of the rivers of the Pacific Coast of North America. *Salmo salar* is seldom known to enter rivers south of the Loire, but prefers the rushing turbulent rivers of Scandinavia, Western Ireland, and Britain; the Pacific Salmon species, however, have a wider area of distribution, being known from the Santa Ynez Mountains in California to as far north as Alaska.

On the other hand, the stream and loch species of Salmonidæ, such as the Brown Trout (*Salmo fario*), the American Brook Trout (*Salvelinus fontinalis*), the Alpine Char (*Salvelinus alpinus*), the Black Spotted Trout (*Salmo clarkei*), the Canadian Great Lake Trout (*Coregonus*), the Bavarian Great Lake Trout (*Salmo lacustris*), the Loch Leven Trout (*Salmo levenensis*), the Grayling (*Thymallus*), and so on, are generally classed as non-migratory, but do show some degree of migration in order to spawn in shallow water. The migratory habit is therefore probably an ancient habit in this family. It may be noted that the Rainbow trout (*Salmo irideus*) of Pacific North America is migratory in some rivers, non-migratory in others. The Canadian Land-locked Salmon (*Salmo salar* var. *sebago*) offers an example of a stock of the Atlantic salmon which became

cut off from the sea by geological disturbances, and has in consequence had to dispense with the extreme migratory habit.

The **life-cycle** of *Salmo salar* or of *Oncorhynchus* is as follows :—

The season of spawning is autumn and winter, usually November and December in Europe, but commencing as early as July in the case of *Oncorhynchus.* The salmon commence to run up the rivers in spring or may run up in autumn. It would seem that salmon of all stages tend to migrate from the sea towards coastal waters every season, and some individuals may even reach the lower reaches of rivers, but only spawning salmon push forward as far as the shallow upper reaches. The sea trout (*Salmo trutta*) and the Pacific salmon apparently do not wander far from the inshore waters near to the estuary of their parent stream, and the Parent Stream Theory, the view that salmon always return to the rivers they were born in, may thus apply to these forms, but almost certainly does not hold good for *Salmo salar.*

As the spawning period approaches, the fish lose their silvery colour, the flesh becomes pale from loss of oil—" white meated " as the salmon canner terms it—the males become hook jawed and distorted. These changes are most marked in autumn, so that spring running fish are far more valuable commercially to the salmon fisher, who relies upon catching the running fish in trap nets in the lower reaches, than are autumn running fish, which, in fact, may be worthless as food.

Spawning takes place in extremely shallow water, to reach which the fish may have had to make their way up the rapids of torrential rivers. The eggs are laid in a hole scooped in the gravel. After spawning, the fish float helplessly down-stream, tail first, and probably few reach the sea again. This is particularly the case with *Oncorhynchus*, owing to the vast distance between head waters and mouth of the North American rivers.

The embryo, or **alevin,** when hatched, measures about half an inch in length. After one summer in fresh water the young fish is termed a **parr.** It is trout-like, with a colour pattern of dark vertical bars on an orange ground. After one or two winters in the stream the parr changes into the migratory phase or **smolt,** the orange ground colour changing to a silver hue. The smolt travels down to the sea, probably in spring. After one winter at sea the fish is termed a **grilse** ; after more than one winter the fish may be termed a **salmon.**

The life-cycle of the salmon is reflected to some extent

in the arrangement of the concentric rings of growth shown by the scales. As shown in Fig. 44, the growth ridges formed during the parr life are fine and close together. The growth ridges formed during sea life are coarser, and those formed during winter are closer together than the summer ones. Further, if the fish has successfully returned from a spawning


FIG. 44.—Diagram of Scale of a Salmon five years old to show Summer Rings, wide apart, and Winter Rings, close together, and Spawning Mark *s*. *e*—exposed part of Scale, on which all but First Year Rings are indistinct.

migration, the former ragged edge of the scale, a consequence of the loss of condition produced by fasting and spawning exhaustion during the run, is marked on the scale by a scar.

Salmon are caught in the European estuaries for commercial sale in considerable numbers, but not to the extent that prevails in the estuaries and lower reaches of the rivers of British Columbia and Alaska, whose salmon canning establish-

ments have supplied the world with the preserved flesh of the Pacific Salmon.

The local names of the five species of *Oncorhynchus* upon which the North American salmon canning industry is based are, according to Tressler, as follows :—

| Scientific Name. | Puget Sound. | Columbia River. | Alaska. | Other Names. |
|---|---|---|---|---|
| *O. nerka* . . | Sock-eye | Blue-back | Alaska red, Sock-eye | Quinnault |
| *O. tachawytscha* . | Spring | Chinook | King, Chinook | Quinnat |
| *O. kisutch* . . | Coho, Silver | Silver | Medium red, Coho | Silversides, Masu |
| *O. gorbuscha* . | Pink | Pink | Pink | Humpback |
| *O. keta* . . | Chum | Chum | Chum | Keta, Dog |

Of these five species, the Sock-eye and Quinnat Salmon form the greater bulk of the canned output. The remaining species are autumn running salmon and their flesh is consequently much inferior, although much of it is smoked or dried and used as food for man and dog by the Indian population of Columbia and Alaska.

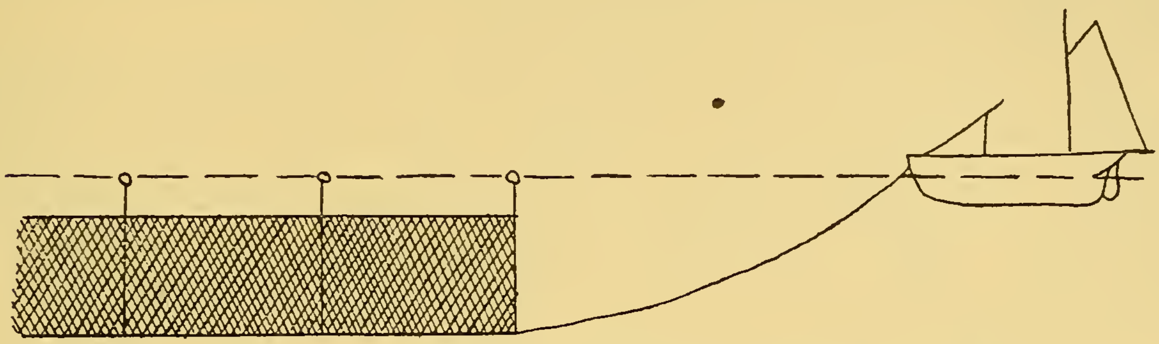
In recent years, however, quantities of the Pink Salmon have been put on the market in canned form. In the rivers of Hokkaido, the northern island of Japan, the Dog Salmon and the Silversides, both autumn running species, are caught and salted in considerable quantity for human food.

The usual method of salmon catching is to catch the running adults in **gill nets,** that is to say, perpendicular nets with a mesh sufficiently large for the fish to push the head through but not the body, so that the salmon attempting to withdraw is caught fast by the gill covers. Such nets are either arranged as stationary nets, held in position by stakes or by buoys and sinkers across the estuary in zigzag fashion, or they are arranged as drift nets, hanging from buoys but drifting with the tides. In some localities nets of smaller mesh are used, either as **seine nets** whose ends can be drawn together so as to enclose the salmon in a circular enclosure or bag which can be drawn to the shore, or as **trap nets,** so staked as to form an elaborate labyrinth-like trap.

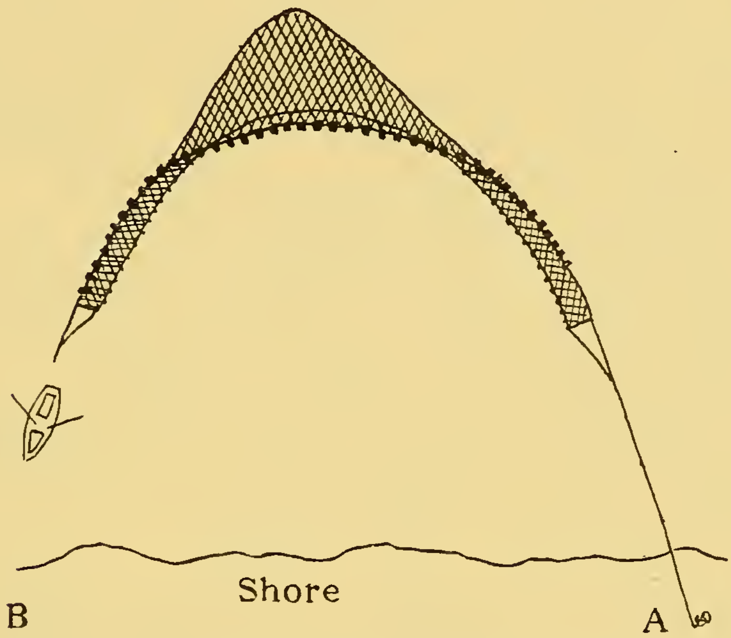
In other localities **fish wheels** are used, operated by the current. These, as they revolve, pick up the salmon and throw them into a box by the side of the wheels.

Gill nets and seine nets are usually termed " floating gear " ; trap nets and fish wheels are termed " fixed gear."

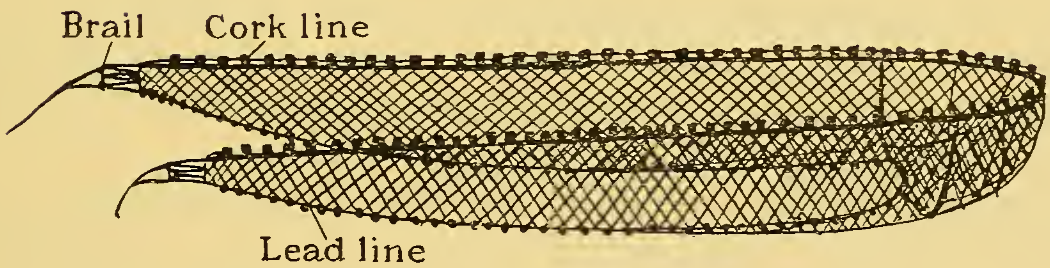
The great objection to fixed gear is, of course, that large numbers of other fishes in addition to salmon, and numbers



Part of a Train of Drift Nets (diagrammatic)
(after Fowler)




Seine Net (after Fowler)




Italian type of Sardine Round-haul Net
or Lampara
(after Thompson)

FIG. 45.—Types of Fishing Net.

of small salmon, are caught, and since no trouble is taken to return them to the water, the destruction of fish life is great.

The canneries, which are worked chiefly by Chinese labour, are situated close to the fishing sites, on the shore, so that at

most only a few hours elapse from the time the fish is swimming freely until it has been caught and delivered to the cannery, beheaded and gutted, washed and skinned, packed into pound cans, steam cooked, and hermetically sealed.

It is obvious that however carefully controlled the methods of salmon catching may be, there is bound to be an enormous restriction of the number of fish that reach the spawning grounds and great danger of the salmon rivers becoming exhausted. Since, however, the discovery of methods of efficiently rearing salmon fry, the danger is being met to a considerable extent in Canada, United States, Japan, and to a less extent in Europe, by the establishment of salmon hatcheries along the head waters of the principal salmon rivers. Female salmon are trapped, their eggs obtained by gently squeezing the animal over a dish, the milt obtained similarly by squeezing the male, the fertilised eggs hatched, and the larvæ reared through to parr in perforated boxes submerged in troughs of swiftly flowing water.

**Sturgeon Fisheries.**—The **sturgeon** (*Acipenser*) is, like the salmon, a marine fish, which is rarely caught at sea but can be caught in numbers in the estuaries of rivers to whose lower reaches the fish migrates in order to spawn. *A. sturio*, the North Atlantic sturgeon, ascends the rivers of North America and Europe, and can be caught in drift nets, although not in such numbers as is the case with salmon.

*Acipenser guldenstadti* and *Acipenser ruthio* (the sterlet) occur in the Black and Caspian seas and are extensively caught in the Volga, the roe of the females being salted and sold as caviare, the swim bladders being exported as isinglass.

*Acipenser transmontanus* and *Acipenser medirostiis* ascend the Fraser, Columbia, and Sacramento rivers of North America, but they are so outbid in importance by the salmon that their capture is not carried out on a commercial scale.

**Eel Fisheries.**—The economic importance of the fresh-water eel as a food fish is considerably less than it was a century ago when numerous Dutch eel boats brought cargoes of live eels up the Thames to Billingsgate market, and eel catching is now but a local industry in Europe. The adult animal is, of course, an inhabitant of streams and ponds, and may be captured therein by trapping or by spearing.

After a period of seven or eight years in the fresh waters, the eel undergoes a katadromous spawning migration to the deep waters of the Atlantic. Prior to and during this migration, the eel takes on the coloration of a deep sea fish, becoming darker

dorsally and silvery ventrally, and developing larger eyes. These silver eels descend the rivers in autumn. They are rarely caught at sea, however, despite the vast numbers that

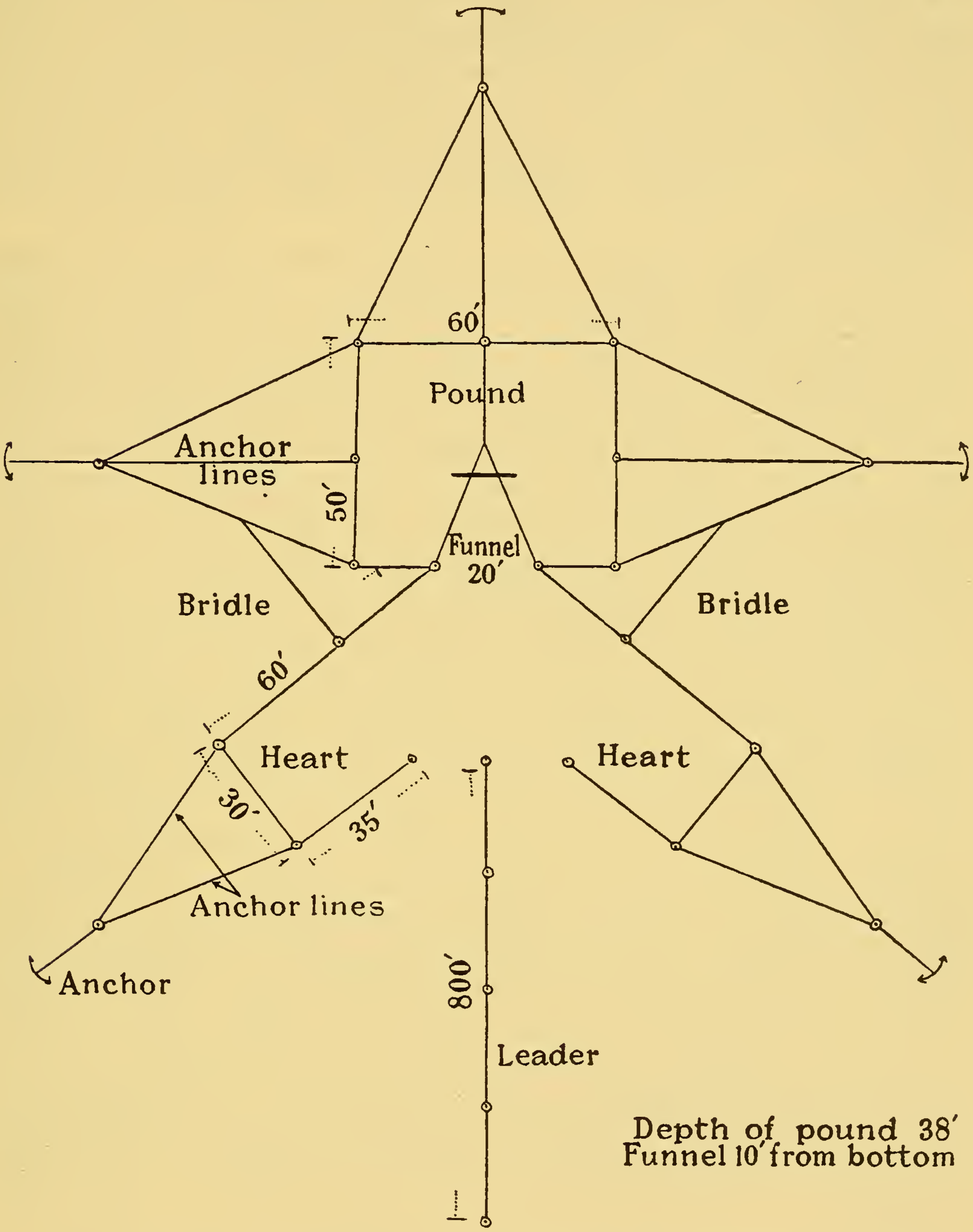



Fig. 46.—A Fish Trap. (From Park Museum Bulletin, Providence, Rhode Island.)

must cross the North Sea fishing grounds every year. The eggs are laid apparently in very deep water, and the transparent ribbon-shaped larvæ, formerly regarded as representing a distinct fish genus *Leptocephalus*, are carried by currents towards the European rivers, or the North American rivers

in the case of American eels. Before entering the river mouth the larva metamorphoses into a **glass eel,** becoming rounded and eel-like. The eel is now an active swimmer rather than a drifter. It apparently hesitates at the river mouth until more deeply pigmented and then ascends the river in enormous masses of **eel fry.** This ascent of vast compact columns of young eels is a well-known annual feature of many European and American rivers, and the eels are captured in enormous numbers but used chiefly for local consumption.

**Fish Rearing.**—Fish rearing or pisciculture may concern itself primarily with **fish hatching,** the rearing of young fishes intended for the restocking of depleted rivers or lakes, in which case the young fishes are not reared beyond the early stages following the larval one; or may concern itself with **fish culture,** the rearing of certain fresh-water food fishes from egg to mature fish. The provision of fish hatcheries for the restocking of salmon streams has already been referred to. Apart from this type of hatchery, the bulk of fish hatcheries in Europe and America, excluding of course the marine fish hatcheries, are intended for the commercial production of trout larvæ or of very young trout. The rearing of trout to a size sufficiently large to be of commercial food value would be a troublesome operation, although actually carried out in some countries, owing to the cannibalistic habits of most trout and to the requirement by captive trout of very cold and well aerated water. In Great Britain the principal species of trout which are reared for restocking of lochs and trout streams are *Salmo levenensis* (Loch Leven trout), *Salmo fario* (Brown trout), *Salvelinus fontinalis* (American brook trout), and *Salmo irideus* (the Rainbow trout). Other species, however, are supplied by some hatcheries. The stages supplied are what is termed *eyed ova*, that is to say fertilised eggs in an advanced stage of development; *fry*, that is to say three month old larvæ; *yearlings*, which vary between three to five inches in length; and *two year olds*, which range from five to nine inches in length.

It must be remembered, with regard to the restocking of trout streams and lochs, that many Salmonidæ are inveterate cannibals. *Salmo fario*, for example, can be a veritable fresh-water shark in ponds or lakes where food is scarce. The Loch Leven trout (*Salmo levenensis*) in lochs where food is scarce, becomes one of the worst of cannibals, and is apt to become a deep-water frequenter and so useless to the angler.

In Canada and the United States, fish hatcheries have been

established also for the hatching and liberation of shad fry (*Alosa*) and White-fish fry (*Coregonus*).

Actual fish rearing, from egg to adult fish, is carried out on a considerable scale in certain European countries, particularly Denmark, France, and Germany, the fish concerned being species of carp. In North America and in Great Britain the commercial rearing of carp is not carried out, since the competition of sea fish keeps the price of fresh-water fish down to a level at which carp culture would not pay.

The **Cyprinidæ** or carp family includes the Carp (*Cyprinus carpio*), introduced into Europe from the rivers of Russia, China, and Japan; the Crucian carp (*Carassius carassius*), widely distributed over Europe and Northern Asia, and extensively reared as goldfish and silver fish in China and Japan; the barbel (*Barbus barbus*) of Central European rivers; the gudgeon (*Gobio gobio*), of Europe; the bitterling (*Rhodeus sericeus*), of Central Europe and Asia; and numerous other species under the names of roach, chub, dace, minnow, bream, tench, and so on. With a few exceptions they are small and feeble fishes, forming most of the food of predatory river fishes, and owe their great abundance to the prolific power of reproduction.

The true carp itself, *Cyprinus carpio*, a native originally of Northern China, where it has been domesticated for centuries, is a dull and sluggish fish which thrives in stagnant ponds or reservoirs and is as omnivorous as the domestic pig. It is, in fact, one of the easiest of fishes to rear in captivity.

The usual practice in Europe is to use shallow artificial ponds or natural drainage ponds, normally covered by water, in the bottoms of valleys too wet for ordinary farm crops, and kept wet by drainage from the fields. The ponds are occasionally manured with liquid manure to encourage the multiplication of small Crustacea and other creatures. The ponds should be calm, exposed to sun heat, and not deeper than eight or nine feet. They are stocked in early summer with fry, purchased from hatcheries, or hatched in small breeding ponds. After three years in the pond the carp are about 2½-3 lbs. in weight, and are sold at this age, as larger and older ones are coarser. Females for spawning purposes are kept up to ten years, but are then useless for food. A little cereal food or household scraps is given occasionally, but the carp feed mainly on the natural resources of the pond. As a matter of fact, intensive feeding methods will produce very rapid growth in carp, particularly in sub-tropical and tropical climates. Thus in California, Mexico, and other sub-tropical areas, carp have reached 15 lbs.

in three years. In China a weight of 30 lbs. in five years is obtained by supplying abundant food.

In Japan, where almost incredible quantities of carp and eels are reared in ponds, a common practice is to place young carp when one or two inches long in the flooded rice fields, in June ; by October, when the rice is cut, these have grown to eight to ten inches long and are quite marketable.

The Goldfish (*Carassius carassius*) is also a common Chinese fish which has become introduced into Europe and America. The wild fish is really an olive-green colour, and a reversion to this colour is commonly shown by races not subjected to rigid selection.

In the hands of Japanese breeders the goldfish has become modified into a number of races, many of the most bizarre and monstrous description.

The eel and the mullet, although often reared in ponds with carp, are not hatched therein, but are caught with the net in spring in any brackish water near at hand and placed in the pond. In the case of eels, special precautions are necessary to prevent them escaping, but their response in growth to intensive feeding well repays the trouble of rearing, provided that there is a market for them.

**Fish Diseases.**—Fresh-water fishes in the artificial environment of fish pond or aquarium or hatchery are subject to a number of ailments, the majority of which, being parasitic in origin, are liable to become far more intensely epidemic under these conditions than is the case under natural conditions.

**Whirling sickness** or "gill trouble" is caused by an intestinal Protozoon, *Octomitus salmonis*. The fish loses its sense of balance and turns over repeatedly in the water with a corkscrew motion. Affected fishes become eventually so weak that they lie on their backs with gills distended. The intestines are filled with a watery fluid swarming with the organisms, and the walls become yellowish translucent. Transmission of the disease occurs through an encysted stage of the parasite, which passes from the fish into the water and becomes ingested by another fish.

**Costiasis** is a disease of the external epithelium caused by the Protozoon, *Costia necatrix*. The skin of an infected fish is marked by slimy patches where the epithelium has sloughed away. In the final phase the gills are attacked and the fish dies of suffocation.

Remedial measures comprise the transference of infected fish to a bath of 2½ per cent. solution of sodium chloride (21 lbs.

table salt to 100 gals. of water), in which they are immersed for ten to fifteen minutes ; four treatments at intervals of three days should be applied. Salt may be used also to disinfect contaminated hatchery troughs.

**Ichthyophthiriasis,** another skin disease, is caused by the burrowing Ciliate Protozoon, *Ichthyophthirius multifilis.* In nature, fish are seldom killed by this disease as, owing to the bulk of medium and the wide range of movement possible to the fish, individual infestation does not become sufficiently intense. In ponds and hatcheries, however, the disease may cause heavy mortality. The skin becomes covered by small whitish-grey pimples, which occur particularly on head, flanks, fins, mouth, and gills ; these are the young parasites. As each parasite grows, the spots become of course larger and tend to run together into patches. There may be hundreds of such spots over the surface of the fish. In later stages the fish is covered with a heavy slime and its skin shows red blotches or "scalded areas." It stops eating and, as the gills become covered, eventually suffocates.

Two methods of treatment are possible. The first method aims at killing the parasites whilst they are on the fish, and consists of immersing the fish for one minute in a bath of 5 per cent. solution of aluminium sulphate ; the second method aims at killing the parasites after they leave the fish, which they do when fully adult, and consists in placing infected fish in troughs of swiftly flowing water, whereby the parasites as they leave the fish are swept away ; it may be added that in an aquarium the presence of tadpoles or of goldfish, which will eat these free swimming adults, does much to restrict the severity of an epidemic of this disease.

**Gyrodactyliasis** or *fin disease* is another epithelial ailment caused in this case by an ectoparasitic Trematode, *Gyrodactylus.* This animal sucks away the superficial tissues of the fish and produces slimy open sores. The fins may become so abraded that the rays protrude as spines, or the fins may be reduced to mere stubs.

This disease is frequently epidemic in hatcheries among fishes of all species and ages. No cure is known. Salt solutions are not effective. Immersion of the infected fish in 6 per cent. aqueous solution of cider vinegar for eight to ten seconds is sometimes recommended.

A family of saprophytic fungi, the **Saprolegniaceæ,** is notorious in including several genera which attack living fishes. Saprophytic normally on dead and decaying insects and the

like, they can attack fish which are in an enfeebled condition or which have skin abrasions, wounds, torn scales, and so offer a foothold for the parasite. The fungus covers the body first as a film, then as a series of white or coloured blotches on head and body, mouth and gills, on the fins and under the scales. From the living fish the fungus can spread to a dead one or a dead insect, and from these again to living fishes. Species of *Saprolegnia* and *Achyla*, in particular, attack salmon during their fresh-water migrations.

Infected fishes may be treated successfully by saline baths or by painting the fish with 50 per cent. solution of hydrogen peroxide in water when the disease is commencing. Once the fungus has secured a hold on the fish, no remedial measures are of any use.

## CHAPTER XXVIII

## INSHORE FISHERIES

It is not easy to draw a clear line of demarcation between the terms inshore and offshore fisheries, but in this chapter the term inshore will be taken as referring to fisheries carried out within ten miles of the coast.

Such fisheries fall naturally into two categories, namely :—

(1) The obtaining or cultivation of sedentary or semi-sedentary animals which live permanently within the inshore limits ; this category comprises the **shell fisheries**, that is to say the procuring of edible molluscs such as the oyster (*Ostrea*), the soft clam (*Mya*), the mussel (*Mytilus*), cockle (*Cardium*), hard clam (*Venus*), scallop (*Pecten*), periwinkle (*Litterina*), etc. ; of useful molluscs such as the pearl oyster (*Margaritifera*), the abalone (*Haliotis*) ; of edible Crustacea such as crabs, lobsters, prawns, shrimps.

This category also includes certain minor fisheries of invertebrate animals such as **sponge fisheries, coral fisheries, trepang fisheries,** and the collection of cuttle-fish and even of barnacles.

(2) The catching of fishes or other animals which come from offshore waters to inshore waters in order to spawn or reproduce. This category includes the various **herring fisheries,** the **fur-seal fisheries,** and such minor industries as the obtaining of sea-birds' eggs and edible bird nests.

The general principles involved can be illustrated by a description of the oyster fisheries, pearl fisheries, and herring fisheries.

**Oyster Fisheries.**—The term "oyster" refers to an edible mollusc of the Lamellibranch or bivalve genus *Ostrea*, of which a number of species exist.

The North European oyster, for example, is *Ostrea edulis* ; the South European oyster is *Ostrea angulata* ; the Eastern American oyster is *Ostrea virginiana* ; the Western American one is *Ostrea lurida*.

The oyster is completely sedentary, being attached usually to a stone by one valve of the shell, and it occurs in colonies or **beds** generally off the mouths of rivers where the water

abounds in the minute sea organisms upon which the oyster feeds. The oyster, however, requires pure water and a firm substratum. The female oyster, or the hermaphrodite oyster, according to species, produces an enormous number of eggs. The newly hatched larvæ, technically termed **fry,** swim about for a period probably of several weeks and each develops a bivalve shell ; then the larvæ sink to the bottom, fasten themselves to a stone or to old oyster shells, and each begins to build a new shell ; they are now described as **spat.** Spat are oysters in the first year of life. In the second year they are termed **brood oysters.** Between two and three years old the oyster is termed **half-ware,** and usually spawns for the first time. Marketable size is reached when four to five years old, and the oyster reaches perfection, from the epicurean standpoint, when six or seven years old.

Marketable oysters are termed **ware.**

A very high degree of mortality occurs among the fry ; many are devoured by predatory animals ; many are swept out to sea by tidal currents ; many cannot find a suitable substratum upon which to settle. The increase in numbers of a bed of oysters under natural conditions, therefore, is very small, in comparison with the numbers of potential individuals produced, and a natural bed of oysters will be very quickly exhausted by commercial dredging methods unless reinforced by some system of artificial cultivation and planting of spat.

The great oyster-breeding grounds of the world, therefore, are almost all artificial, in the sense that they are controlled by human agency.

The methods pursued in oyster cultivation may be illustrated in principle by a description of those made use of in the French oyster beds of Arcachon, probably the earliest and certainly the most famous centre of oyster rearing.

An oyster-rearing site should be situated, preferably, on a firm substratum of fine gravel or hard mud, should not be subject to violent tidal movements which would sweep large numbers of fry out to sea, and should be provided with suitable objects for spat to settle upon.

The physical feature which makes Arcachon such an ideal centre for the production of oyster spat is the existence of a vast inland sea, the " bassin d'Arcachon," of about 30,000 acres in area, connected with the Atlantic by a narrow entrance through which the tide runs in and out. In the middle of the basin there is a small island, Ile des Oiseaux, and on the shores of this are situated the oyster farms or " parcs." Some of

these belong to the Government and are reserved for the production of spat. Others are leased to individuals and companies. The oyster spawns at Arcachon between May and early July, so that at some time during this period the cultivators place in position numbers of earthenware tiles covered with lime cement for the fry to settle upon.

These tiles are stacked in layers in wooden frames to a height of three feet. By October the tiles are covered, each with hundreds of well-established spat. They are then removed and the tiny oysters are flaked off with a knife and placed in "ambulances," which are flat trays having a floor and lid of half-inch wire netting. These trays are placed between short posts in the sea on the oyster parc so that the tide can run freely through them. They are constantly examined, and enemies and impurities removed. In these trays the young oysters grow rapidly and have soon to be thinned out.

A considerable area of the oyster parc is divided into little fields demarcated by hedges made of bunches of the local heath (*Erica scoparia*). These enclosures at low tide are covered by about six inches of water, swarming with micro-organisms, especially diatoms, and the young oysters after transference from the "ambulances" to these enclosures grow very rapidly. The choicest French oysters, however, are those reared at Marennes, farther along the coast. Young oysters from Arcachon are sent there and fattened in shallow artificial ponds, termed "claires," in the salt marshes. These claires swarm with diatoms, particularly a species termed *Navicula fusiformis* var. *ostrearia*, and oysters fed in these claires become particularly fat and acquire a greenish-blue colour; such oysters are particularly esteemed by the epicure.

Methods of oyster cultivation in other parts of the world are similar to those of the French areas. In Holland the chief area is a land-locked lake, formed by the damming of the east arm of the Scheldt. In England, off the coast of Essex, the method is to lay out numbers of oyster and cockle shells on the foreshores just before the spawning season and to strip the spat during the summer of the following year. All oysters are dredged up in autumn, kept in pits near high-water mark during winter, and sown out again in the following March or April. This course is adopted because of the ice-cold water which comes down the rivers in winter and kills large numbers of oysters.

In Canada and the United States the oyster is the most valuable fish product; it furnishes one-third of the total value

of all fisheries of the latter country. In fact, the shallow, gravelly bays and estuaries along the eastern coast of North America, especially between Cape Cod and Cape Hatteras, seem to offer the best conditions in the world for oyster production. Good beds, however, occur as far north as Prince Edward's Island and as far south as the Gulf States. On the tidal flats of the western coast, particularly of California and Washington and British Columbia, carloads of spat are planted annually with *Ostrea virginiana* from the eastern coast. The larvæ of this oyster, however, are killed by the low temperatures prevailing during the spawning season on the Pacific Coast, so that the beds have to be constantly replanted. The oyster fisheries have developed in importance largely through the establishment of a considerable canning industry.

There is also a large oyster culture industry in Japan, particularly at Hiroshima, the beds being parcelled out in enclosures. The methods employed are similar to those of Europe, but branches are used instead of tiles for collecting the spat.

Shortage of *Ostrea edulis* in European oyster beds brought about some years ago an introduction of American oysters into many of the British oyster fisheries. Unfortunately, with the American oysters came the American Slipper Limpet (*Crepidula fornicata*), which, although not a predator on the oyster, attaches itself in large numbers to the oyster valves, and competes very seriously for space and food. In some localities it is possible to dredge 20 tons per day of *Crepidula* on the oyster beds. It is a prolific breeder and, when once established, impossible to eradicate.

**Other Shellfish Industries.**—Apart from the oyster, the collection of edible molluscs such as the cockle, mussel, scallop, clam, and so on, has no more than a local value, and these industries are the most miserable and poorly remunerated of fishing industries. Crab, lobster, and shrimp fisheries, however, are of considerable importance in certain areas, but owing to the difficulty of transporting such perishable food-stuffs, the products are as a rule consumed locally.

In Eastern Canada and Newfoundland, however, owing to the establishment of canneries, the lobster fishery has become very valuable, and is probably the most productive lobster fishery in the world. In spite of the establishment of artificial hatcheries and of severe legislation, however, the lobster fisheries of Canada and North-eastern United States are declining owing to the difficulty of enforcing legislation

concerning close seasons, size limits, and protection of the egg-bearing females.

Methods of capturing Crustacea are much the same in all countries. Crabs and lobsters are trapped in basket traps or box traps ; prawns and shrimps are taken in hand nets or are trawled for by half-decked fishing boats of about 10 tons register. Prawns and shrimps are also brought in from off-shore waters by the steam trawlers.

**Pearl Fisheries.**—Natural pearls are produced by a variety of Molluscan species. They may be produced, for example, by the fresh-water Mollusca, *Unio* and *Anodon*, of Europe and North America, by the edible oyster, by the edible mussel (*Mytilus*), by the abalone (*Haliotis*), and so on ; but the finest pearls, the so-called Oriental Pearls, are the product of the Pearl Oyster (*Margaritifera* or *Meleagrina*), which occurs in shallow water lagoons in the Pacific and Indian Oceans.

Pearl formation by the mollusc may be described as a disease, inasmuch as it represents a secretion of the pearly substance, that forms the inner layer of the shell, around some foreign body which is causing the oyster considerable irritation.

There is some difference of opinion as to what this foreign body may be. The prevailing opinion seems to be that, in a certain number of cases, it is a grain of sand, in other cases a particle of calcareous substance within the muscles, and in the great majority of cases a parasite, a larval stage of a fluke or tapeworm.

That the presence of a particle of inorganic matter can stimulate the pearl oyster to produce pearls seems evident from the remarkable success of the Culture Pearl industry, established by Professor Mitsukuri in Japan and peculiar to that country. *Margaritifera* is cultivated in millions by methods similar to those used in the production of *Ostrea*.

Many natural pearls are of course obtained, but many more are obtained by introducing a particle of inorganic matter—the exact method is a secret—between the valves of the oyster. The culture pearls thus produced, however, are very often attached to the inner shell layer, and do not lie freely in the space between the valves as do true pearls. A really good culture pearl, however, is almost impossible to distinguish from a natural one, except by X-ray methods, and is just as effective ornamentally.

The term culture pearl must, of course, be distinguished from the term artificial pearl. Artificial pearls are now produced in enormous quantities by coating solid opal glass beads with

"pearl essence," which is a suspension of crystals of guanidine in gelatine, obtained by treating fish scales with aqueous ammonia, acetone, amyl acetate or similar solvents.

**Pearl Fishing Grounds.**—With regard to the geographical situation of pearl fisheries, a distinction must be made between those fisheries whose primary object is the securing of pearls and those fisheries whose chief object is the pearl oyster shell or mother-of-pearl. The chief fisheries for the pearls themselves are the Persian Gulf, the Gulf of Manaar, the Red Sea, and to a less extent those of Venezuela and Panama.

The Persian Gulf fisheries employ about 35,000 persons, and cover an area of about 600 by 100 miles with Bahrein Island as headquarters. The beds consist of level areas of rock, coral débris or sand, two to eighteen fathoms deep. The oyster concerned is *Margaritifera margaritifera*. The fishing is carried out by Arab divers, who fasten heavy stones to their feet to bear them down. The pearls are sold chiefly to the Mahomedan and Hindu merchants of Bombay.

The Manaar fisheries have been almost extinguished by a succession of barren years. They were carried out in the Gulf of Manaar, an arm of the Indian Ocean, 65-150 miles wide, separating Ceylon from Southern India, and in the neighbourhood of Tuticorin on the Madras coast of India. These fisheries, which are very ancient, depend upon the fact that certain patches of rock termed "paars," which lie within half a mile to eighteen miles from the shore, and in water not more than fifteen fathoms in depth, are covered in certain years with copious deposits of the pearl oyster, *Margaritifera vulgaris*. The occurrence of these deposits is most erratic, and two or three years of productive fishery may be followed by a number of years when scarcely any oysters are to be found. Thus, prior to 1903, there had been a break of twelve years. In 1903, 1904, and 1905, oysters were present in phenomenal abundance, and then ensued another barren period of years, so disastrous as to bring about in 1912 the failure of the Ceylon Company of Pearl Fishers Ltd., which had been formed in 1906 to lease the oyster paars from the Ceylon Government and to exploit them. A biological Commission, appointed by the Royal Society of England at the instigation of the Ceylon Government, had made an extensive faunistic survey of the area between 1903-06, and had attributed the intermittent character of the fisheries primarily to the destruction of oyster beds by shifting sands and by predatory fishes of the Skate-ray family, and secondarily to overcrowding.

Recommendations of the Commission to the effect that transplanting and cultching, that is to say, the strewing of sandy areas of the sea bottom with broken rock for spat to settle upon, should be undertaken, were faithfully carried out by the Company but without appreciable success in provoking the appearance of oysters.

Very great stress has been laid by some authorities upon the importance of protecting the paars from predatory rays either by destruction of such fishes or by guarding the beds with wire netting, but until it is established with certainty that the provoking cause of pearl secretion in the Ceylon oyster is or is not a stage of a Tetrarhynchid tapeworm living in these rays, destruction of these fishes can hardly be recommended. On the other hand, it is apparently not beyond possibility that years of oyster abundance on the Ceylon beds arise, not from abundant spatfall of preceding years, but from the conveyance of floating oyster larvæ on surface currents from the south-eastern coast of India during very strong and prolonged south-west monsoons.

The Red Sea fisheries are of minor importance. The oyster fished for is *Margaritifera margaritifera erythrœnsis*, closely related to the Persian Gulf species. Pearls are rare but the shell affords a good quality of mother-of-pearl.

The shell of the pearl oyster is in considerable demand for the manufacture of mother-of-pearl ornaments, jewellery, buttons, and so on. The chief species of oyster whose shell is so made use of are : *Margaritifera maxima*, the large white shell of Australian, Papuan, and Malayan waters, commercially known as " silver lip," " gold edge," " manila shell," or " Queensland Mother-of-Pearl." It is fished for in the Persian Gulf :

*Margaritifera cumingii*, a dark coloured shell from Polynesian waters, known commercially as " Auckland Shell," " Taluti Shell," " Black Shell," and used for the production of smoked pearl buttons :

*Margaritifera vulgaris*, commercially known as " lingahs," valuable only for cheap qualities of shirt buttons.

The chief fisheries for pearl shells are those along the coast of West Australia from Cape York to North-west Cape, in Torres Straits and off Queensland.

Other molluscs besides *Margaritifera* are valuable in this way. Thus certain species of *Haliotis*, popularly termed abalones, notably *H. splendens*, *H. iris*, and *H. mida*, are fished for along the coast of Japan and California. They are obtained, as are pearl oysters, by divers. Apart from the shell

value, occasional pearls occur, and there is a considerable flesh value, large quantities of dried abalones being shipped from Japan and California to China.

**The Herring and Mackerel Fisheries.**—The majority of the Herring family (*Clupeidæ*) and the Mackerel family (*Scombridæ*) of fishes are marine fishes of considerable food value. From the economic standpoint, the more important members of these families are the **Atlantic herring** (*Clupea harengus*), the **sprat** (*Clupea sprattus*), the **pilchard** or **sardine** (*Sardina pilchardus*), the **anchovy** (*Engraulis encrasicholus*), and the **shad** (*Alosa*), of the Clupeidæ; the **mackerel** (*Scomber scombrus*), the **bonito** (*Sarda sarda*), and the **tunny** (*Thunnus thynnus*), of the Scombridæ.

These fishes possess the anadromous habit to a more or less extent. The shad migrates into the estuaries of rivers; the others migrate from offshore waters into inshore waters to spawn, and the presence of adult fishes and of young fishes in the coastal waters at certain times of the year has determined the extent to which these fishes form the basis of fishing industries.

The **herring** appears at certain times of the year in enormous numbers, termed "shoals," covering an area of one to fifteen square miles, within the coastal waters along the eastern and southern shores of Great Britain, the Irish Sea, the Scandinavian coast, the shores of the Baltic, and Eastern Canada. These shoals appear at night, swimming against the tidal currents, and near the surface. The usual method of catching them, therefore, is by drift nets, perpendicular walls of gill netting fastened together to form "trains," often two to three miles long, but only eight yards deep. These trains are buoyed and weighted, and are sunk at right angles to the direction of the tide to a depth at which the shoals are likely to be swimming. The nets are allowed to drift with the tide. The fishing takes place, of course, at night (Fig. 45).

The boats are usually privately owned, but gather together in large fleets composed chiefly of British, Norwegian, French, and Dutch boats. The steam drifter, which is replacing the sailing boat, carries a crew of ten, who share profits. The fleet works in proximity to some landing centre, for herrings must be landed quickly. This centre moves south as the season advances, for reasons which will be discussed presently. The principal centres are Stornoway, Peterhead, Fraserburgh, Yarmouth, Lowestoft, and to a less extent Boulogne.

At these centres the bulk of the catch is either salted in


FIG. 47.—Probable Migrations of a Shoal of Pilchards carried in the " O " Stage up Channel (......) and the General Migrations of the Spent Fishes (---------->). Spawning Grounds and Drift of Fry of Herrings (○——————>). Roman numerals indicate months of year. (All after Meek.)

barrels of 800-1,200 fish, an extensive export trade being carried out with Baltic countries, or is sold to the curers for preparation as smoked bloaters, kippers, and red herring. A comparatively small proportion of the catch appears on the market in fresh form.

The important feature of the herring fishery, from the scientific standpoint, is that the shoals of fish appear in inshore waters progressively later in the year in the south than in the north. Thus they appear in Norwegian waters in March; off the Shetlands, Orkneys, and the Northumberland coast during the so-called "Scottish Season" of June, July, and August; off the Yorkshire coast during the so-called "Yarmouth Season" of September; and do not appear in the Channel until December (Fig. 47).

The explanation of this progressive appearance of herring shoals formerly put forward was that the herrings came down from the Arctic Circle as a great army and divided into western and eastern divisions, the latter of which travelled southwards between Great Britain and the Continent, but returned northwards along the western coast of Britain and Ireland.

This interesting theory, however, has become discredited by the enormous amount of information accumulated by the Fishery Research Boards of those countries concerned in the fisheries, especially Norway, Denmark, Scotland, and England.

The explanation seems to be somewhat as follows :—

(1) There are a number of spawning grounds situated as shown in Fig. 47, that is to say, off the Scandinavian coast, along the eastern edge of the North Sea, the Dogger Bank, Skager Rack, English Channel, and so on.

(2) Each of these grounds is visited annually by a particular local race or school of herrings whose individuals show common features of size and age, and tend to keep together during the years of immaturity and even after maturity.

(3) These local races form two groups, a **coastal group** of races which are winter or spring spawners and come farther inshore than the others, and an **oceanic group** of races which are summer and autumn spawners and do not come so far inshore.

The coastal group includes the herrings of the Channel, Irish Sea, western Scottish lochs and estuaries, Orkney and Shetland Islands, Norwegian fiords Zuider Zee, Western Baltic.

The oceanic group comprises the schools of the Western North Sea, and the schools which spawn at the Shetlands in September, at the Dogger Bank and Skager Rack in October.

The young herrings produced from the spawning of these

schools are carried down the coasts with the tidal currents. Enormous masses of young fish, almost certainly the product of coastal races, are brought by favourable currents between April and September into the Norwegian fiords, the bays of the Northumberland coast, the mouth of the Thames, Morecambe Bay, and so on, and are captured in seine nets to be put on the market as **whitebait**; the Norwegian whitebait form the basis of an extensive canning industry located at Stavanger which competes with the sardine industry. Whitebait consist chiefly of herrings about six months old, and of sprats.

There is a so-called sardine fishing industry carried on also in the coastal waters of Eastern Canada and New England, but the fish used are young coastal herrings which come so far inshore that they can be captured in "brush weirs," that is to say, labyrinthine traps made of wickerwork similar in plan to trap nets. Similar to these are the "madragues" or tunny nets of the Mediterranean coasts, and the bamboo trap nets of Japanese fishermen.

The most important herring fishes caught in American waters, however, are the alewife or river herring (*Pomolobus pseudoharengus*), the shad (*Alosa sapidissima*), both of which migrate far up the rivers of Eastern North America, and the menhaden (*Brevoortia tyrannus*), a coastal herring captured in large numbers for the oil which it yields.

The **pilchard** or **sardine** of Atlantic waters is more southerly in its range than the herring, being restricted to the Mediterranean Sea and the coastal waters of the Atlantic from Madeira to Southern Ireland and Devon. There are two races or varieties, namely, *Sardina pilchardus pilchardus* of the Atlantic, the basis of the French and Portuguese sardine fisheries, and *Sardina pilchardus sardina* of the Mediterranean.

There is apparently a spawning area in the northern portion of the Bay of Biscay, for the first named of these races, from which spent fish travel towards the English Channel and form the basis of the Cornish pilchard fishery, and from which young pilchards eventually appear in the inshore waters of the Biscayan and Portuguese coasts to be caught in seine nets and canned as sardines (Fig. 47).

Along the western coast of America, from Peru northwards to Mexico, occur two other closely allied races or species, namely, *Sardina sagax* and *Sardina cœrulea*. Upon these depends the extensive Californian sardine fisheries. On this coast the fish are caught in a peculiar circular type of seine net termed the "lampara net" (Fig. 45).

On the other side of the Pacific occur the Japanese sardine *Sardina melanosticta* and the Australian sardine *Sardina neopilchardus*. In the waters off the Cape of Good Hope occurs *Sardina ocellata*. The interrelationships of these various species and their morphological characteristics are insufficiently known.

The **sprat** (*Clupea sprattus*), a smaller fish than the herring, is confined to the North Sea region. Like the herring, it occurs in schools or local races, which appear at certain places along the North Sea coastline, especially in the Channel, the South-western North Sea, the Baltic, and Western Norway.

The **anchovy** (*Engraulis encrasicholus*) has a range similar to that of the pilchard, although it migrates as far north as Norway. There is a spawning area in the Zeider Zee, where the principal anchovy fishery is carried on.

It is of interest to note that the pilchard and the sprat are comparable in many respects to coastal herrings; they are small Clupeoids, they are winter spawners, they come well into in-shore waters, and their young forms may be carried into river estuaries. Like coastal herrings, therefore, they may be captured not only by drift nets, but in many cases by seine nets.

A seine net or drag net is a long shallow net supported by cork floats and weighted by lead sinkers, one end of which is fixed on shore, the other end being carried out by a rowing boat along a course which forms a semicircle to the coastline. The boat finally returns to shore and the net is gradually dragged to the shore, thus sweeping a considerable area of water (Fig. 45).

Another type of seine net is the purse seine, used in deep water or out at sea. This net is drawn round a shoal of herring or mackerel by two boats, and the circular enclosure thus created is hauled alongside a steamer and the catch bailed by means of a net bag into the hold. This type is extensively used in the herring fisheries of the Scandinavian fiords and Scottish lochs.

Some type or other of trap net or seine net is in use all over the world, since in the development of fishing industries in every area, inshore fishing has preceded the more difficult offshore methods of fishing. As boats and gear improve, the tendency is always to seek fish farther out at sea.

**Mackerel Fisheries.**—The mackerel fishery is, so to speak, the younger sister of the herring fishery. The **mackerel** (*Scomber scombrus*) is common in the Mediterranean, in the east Atlantic from the Canaries to West Scotland, and in the North Sea, along the West Atlantic from Cape Hatteras to Labrador.

Like the herring, it migrates into coastal waters to spawn, and during the period May to July can be caught in drift nets. In the winter it retires to deep water, and in the North Sea is very often taken in trawls. The migrations of the mackerel are not fully known, and our ignorance of the question has led to considerable dispute between Canada and the United States concerning the rights of fishery in the Gulf of St Lawrence. The Canadian opinion regards the mackerel as a local fish, moving between shore and deep water in the immediate vicinity. On the other hand, the United States authorities hold the view that the migration is from deep Atlantic water to the coast. Further, the mackerel catches on the American coast have steadily decreased, and the suggestion has been made that the mackerel are leaving the West Atlantic and migrating permanently to the other side. This decline is a matter of immense importance since the Massachusetts and Maine mackerel fisheries have been always the most important fisheries of Eastern North America, and the largest mackerel fisheries in the world.

Another of the Scombridæ, the **tunny,** is the object of important fisheries in the Bay of Biscay and off the coast of Tunisia. The term "tunny" refers variously to the albicore (*Thunnus germo*), to the gigantic true tunny (*Thynnus thynnus*), and to the bonito (*Sarda sarda*).

It must not be assumed that Clupeoid and Scombrid fishes are the be-all and end-all of inshore fisheries. In every area of the world where fishing is carried on there are hosts of edible inshore forms whose capture forms the object of important local fisheries. Thus along European coasts there are considerable captures of dab, plaice, whiting, pollack, hake, conger, mullet, sand eels, wrasse, bream, bass, sea perch, gurnards, dogfishes, and so forth.

Every coast, in fact, has hordes of edible animal products peculiar to that particular area.

## CHAPTER XXIX

## OFFSHORE FISHERIES

OFFSHORE fisheries do not necessarily imply deep-water fishing, although the misleading term of deep-sea fisheries is often applied to them. Many of the offshore fishing grounds, in fact, are in water as shallow as the coastal fishing grounds. The term refers rather to fishing grounds which are at such a distance from the landing centres as to necessitate the boats remaining out for a period of days or even weeks. Such a mode of fishing therefore requires boats of considerable size, preferably steam powered, provided with fishing gear adapted to catch fish rapidly and in quantity, and requires the provision of some system of preserving the catches or of rapidly bringing them to market. Offshore fishing, on a commercial scale, is therefore chiefly carried out by joint-stock companies owning fleets of steam trawlers or liners, and possessing headquarters at some particular landing centre where the vessels can be rapidly unloaded and can be rapidly provided with coal and ice, and where arrangements for marketing or preserving the catches are available.

The offshore fishing industries are confined almost entirely to countries bordering upon the North Atlantic, and centre around such ports as Grimsby, Aberdeen, Hull, London, Lowestoft, Yarmouth, Fleetwood in Great Britain ; Esjberg in Denmark ; Geestemunde, Cuxhaven, Bremerhaven, Altona in Germany ; Aalesund, Bergen, and Stavanger in Scandinavia ; Boulogne, Fecamp, Arcachon in France ; Ijmuiden in Holland ; Gloucester, Boston in the United States ; Halifax, Yarmouth, Luxembourg, Canso in Canada ; St John, Newfoundland.

**The Atlantic Fishing Grounds.**—Surrounding the coastline of the continental land masses there is a belt of sea whose depth rarely exceeds 100 fathoms ; that is to say, between the coast and the oceanic depths there is a broad ledge which slopes gradually from the coast to the 100 fathoms line, beyond which the depth of the sea bottom becomes suddenly very great. This submarine ledge is termed the **Continental Shelf.**

The belt of sea which covers this shelf is far richer in marine

life than are the waters covering the oceanic depths, owing to certain favourable physical factors—light, low salinity, greater content of dissolved nitrogen, greater oxygen content, and so forth—which encourage the growth of minute floating plant organisms and minute floating animal organisms, and indirectly encourage the presence of the vast variety of marine creatures which depend for sustenance upon this **plankton** or minute marine life. This richness in marine life is particularly the case in polar and temperate waters, and the most productive fisheries are situated in such latitudes.

At certain points along the continental shelf there occur areas where conditions seem exceptionally favourable to fish life. These areas are generally marked by the occurrence of sandy or rocky plateaux, and termed in fishing parlance **banks**; they are generally characterised by a mingling or a contact of cold Polar currents with warm Equatorial currents and by numerous vertical currents (Fig. 48).

Many such banks probably exist, but the fishing value of many of them has yet to be explored, and others are either too far from the commercial fish-landing centres or they are unsuitable owing to depth, or to the nature of the bottom, for present-day fishing methods.

The greatest offshore fishery sites of the world are, in fact, very few in number and comprehend the following localities :—The **North Sea Banks**; the **Iceland Banks**; the **Newfoundland Banks**; the **Atlanto-Saharan** or **Morocco Banks**; the **Lofoten Banks**; the **Barents Sea** and **White Sea Banks**; and the **Korean Banks** of the Pacific Ocean.

These fishing grounds may now be discussed in more detail.

The **North Sea Banks** was the birthplace of modern trawling methods. The discovery of the potentialities of the Dogger Bank by Brixham trawlers in the nineteenth century, and of those famous haunts of the sole—the Silver Pits—in 1837, led to the development of the British East Coast fisheries and to the predominance of Grimsby and Hull among the fishing ports of the world. After the Silver Pits were discovered, the Dutch, Schleswig-Holstein, and Danish coasts were in turn exploited, and ultimately the Great Fisher Bank to the northward of the Dogger. The extraordinary value and fertility of the North Sea as a fishing ground are due to the extreme shallowness, the average depth being sixty fathoms, the consequent abundance of plankton, added to by the abundance of organisms brought in by the Gulf Stream, the high nitrogen content and low salinity produced by the large volume of fresh


Fig. 48.—The Atlantic Fishing Banks.

1, North Sea. 2, Newfoundland. 3, Iceland. 4, Atlanto-Saharan. 5, Lofoten.

(Map taken from Fowler.)

water entering the area from the Baltic and North Sea rivers, and the favourable geographical situation amidst countries of dense population. There is a greater variety of edible fish in the North Sea than in any other fishing area.

Cod-fish, herring, and haddock predominate, and make up 90 per cent. of the supply. The sole, turbot, and brill occur there but are unknown farther north. Different banks are characterised by different kinds of fishes.

The **Newfoundland Banks** cover an area exceeding that of Italy, lying 50-150 miles off the estuary of the St Lawrence, and marked by a contact between the Gulf Stream and the Labrador current. The suspended matter deposited by melting icebergs, by the meeting currents and by the emerging St Lawrence, has built up in course of time a number of sand banks, extending from Brown's Bank off the western end of Nova Scotia to the "Grand Bank" south of Newfoundland.

Cod are the principal fish taken, but haddock, hake, pollack, and halibut are plentiful. The banks are worked by Nova Scotians, by New Englanders, by the Bretons, and to some extent by English.

The **Iceland Banks** were discovered in 1891, and now supply a great proportion of the trawl-caught fish landed at East England ports. The sandy banks in the shallow water adjacent to the Faroe Isles and on the continental shelf surrounding Iceland, supply large quantities of cod, haddock, lemon soles, plaice, and halibut. The fish from the Faroe Banks are light coloured; those from the Iceland Banks are much darker. The shallow waters between Iceland and Greenland offer great future possibilities.

The **Lofoten Banks** occur parallel to the Scandinavian coast, but separated from it by a deep channel, too deep for trawling. Great shoals of migrating cod visit these banks in spring in order to spawn, and are extensively fished.

The **Barents** and **White Sea Banks** lie north of the Scandinavian peninsula. Though exceeding in extent the Mediterranean Sea, they can be fished only in late summer and early autumn, when the invasion of the Gulf Stream causes the ice to retreat and brings in large quantities of plaice, cod, and haddock. In late autumn the Arctic water predominates and the region becomes icebound.

The **Korean Banks,** which lie on the north-eastern coast of Asia, have great possibilities but are accessible only to Japan among fishing nations.

**The Edible Fishes Concerned.**—The commercial value of

offshore fisheries depends upon the capture and marketing of the members chiefly of two important families of fishes, namely, the **Gadidæ** or cod family, and the **Pleuronectidæ** or flat-fish family.

The **Gadidæ** is a family of fishes characterised by a general resemblance to the North Atlantic Cod-fish, *Gadus callarias*, one of the best known of food fishes and the subject of economic fisheries of the greatest importance. The family includes also *Gadus æglefinus* (the haddock), *Gadus merlangus* (the whiting), *Gadus virens* (the coal-fish), all of similar distribution to the cod; and *Gadus pillachois*, the pollack of the North-east Atlantic.

These fishes do not migrate inshore to spawn as was formerly thought to be the case, but spawn well offshore in those areas which constitute fishing banks, and the floating eggs and newly hatched larvæ are carried towards the inshore waters by the prevailing currents. Thus the Atlantic cod spawns between February and May, when the waters are coldest, principally off Newfoundland, the south and west coasts of Iceland, the Norwegian coast, especially the Lofoten and Romadal banks, and in the North Sea, but not south of that.

The **Pleuronectidæ** or Flat-fishes also comprise many well-known food fishes. The family falls naturally into four tribes, namely :—

(*a*) The Halibut tribe (*Hippoglossinæ*), nearly altogether Pacific in distribution and nearly all northern. The Halibut (*Hippoglosses vulgaris*) and the Long Rough Dab (*Hippoglossoides limanoides*), however, occur in Atlantic waters.

(*b*) The Plaice tribe (*Pleuronectinæ*) predominantly northern in distribution. The Atlantic species include the Plaice (*Pleuronectes platessa*), the Flounder (*P. flesus*), the Dab (*P. limanda*), the Lemon Dab (*P. microcephalus*), and the Witch (*P. cynoglossus*).

(*c*) The Sole tribe (*Soleinæ*), tropical in distribution, abounding on sandy bottoms in the warm seas along the continents. The Common Sole (*Solea vulgaris*), however, occurs in the Atlantic as far north as the North Sea up to the Skager Rack.

(*d*) The Turbot tribe (*Psettinæ*), typically tropical, but occurring in the Atlantic, especially the Turbot (*Psetta maximus*) and the Brill (*Psetta lævis*). Turbot and brill are without doubt the most delicious of flat-fishes, and together with sole are classed by the English fishermen as "prime fish."

All the members of the flat-fish family agree in the habit of lying on the sea bottom on one side. Associated with this

habit is the lateral compression of the body, the lack of pigmentation of the concealed side, and the occurrence of both eyes and the mouth upon the upper side, owing to a twisted condition of the head. That these morphological features are a secondary result of the sedentary habit seems indicated by the fact that larval flat-fishes are always bilaterally symmetrical and undergo, each in its life-cycle, the twisting of the head, which brings eyes and mouth to a unilateral position. As a rule the pigmented side, which bears the eyes, is the left side; that is to say, the fish are *sinistral.* The members of the halibut tribe, however, have pigmentation and eyes on the right side; they are *dextral.* In spawning habit, flat-fishes are katadromous, that is to say, they move towards deeper water to spawn. The eggs and fry, however, become carried into inshore water, and young plaice are found particularly in shallow waters lying over coastal banks. As they become larger, however, they tend to frequent deeper and deeper water, where they mature. In cold weather, when deep water gradually becomes somewhat warmer than the shallows, they tend to creep into the lower depths or "pits" of the fishing banks.

**Offshore Fishing Methods.** — The commercial methods of obtaining offshore fishes are two, namely, **trawling** and **lining.**

The principle in trawling is of course the dragging of a conical net with a widely open mouth over the bottom of shallow waters. Present-day trawling is generally carried out by one or other of two types of such net, namely: (1) the **otter trawl**; (2) the **beam trawl.**

The otter trawl consists essentially of a conical bag of netting (2-2½ inch) about 130 feet long and 90-100 feet wide at the mouth. The tail end, or *cod end* as it is termed, is of finer mesh and its upper and lower surfaces are laced together except for a passage in the centre which has a valve or flap of netting to prevent the escape of the fish netted.

This cod end is separate from the "belly" of the net but laced to it, and so readily removed when the whole net is hauled up into the hoisting tackle. The mouth of the net is kept open by a large iron-edged board on each side, in shape and size comparable to the top of a billiard table. It is known as the *otter board.* To these boards the drag ropes are attached and so arranged that the pull upon them, combined with the resistance of the water, separates the boards and keeps the mouth of the nets open. The deadliness of the otter trawl results from the fact that the upper edge of the net may be as high as twenty-five feet or more above the sea bottom, and is

thus liable to enclose fish which swim a considerable height from the bottom. The upper edge of the trawl may be supported by a series of glass globes, a recent French invention, which makes the edge of the trawl skim the bottom rather than dig into it. In addition, there is a heavy *ground rope* provided with wooden rollers to stir up fishes lying flat on the bottom and make them rise into the mouth of the net.

The beam trawl, which is the older type of trawl, has a net similar in shape to that of the otter trawl but with a mouth about seventy feet width. The mouth is kept open horizontally by a long beam of oak and vertically by a pair of iron runners or heads.

The modern steam trawler is nowadays a specially designed steam vessel provided with automatic sounding apparatus, and with two otter trawls each of about 100 feet width which can be hauled in by steel ropes wound on the drums of steam winches. The vessel is provided also with compartments for storing large quantities of ice.

The beam trawl is carried by the older type of yawl-rigged smack of about 80 tons register with supplementary engine, a type which is restricted to home waters and is passing away.

Trawling is carried out in the North Sea principally for cod, haddock, plaice, and ,to a less extent, for whiting, skates, rays, lemon soles, etc. Outside the North Sea, trawlers visit the Iceland Banks, the White and Barents Seas, and the Morocco banks for cod, haddock, and plaice, and in deep water for the hake (*Merlucius vulgaris*).

**Lining,** although not so commercially important as trawling, is nevertheless employed to a considerable extent in offshore fishing where, owing to an unfavourable sea bottom, or for other reasons, trawling is impracticable. It is the chief method, for example, used in the Newfoundland Banks cod fisheries, because the nature of the bottom there is imperfectly known, and because there is not a large and ready outlet in Eastern Canada and New England for all kinds of fresh fish at good prices such as is required for the profitable pursuit of a steam trawling industry. The bulk of the Newfoundland Bank product is salted and dried and exported largely to Southern Europe at low prices. Fears as to the effect of a steam trawling industry upon the abundance of fish in this area are probably ungrounded, since climatic conditions alone enforce a non-fishing period for three or four months of each year that coincides with the spawning season of cod, haddock, hake, and such fish.

The lining is carried out from *dories*, small, peculiar, flat-bottomed boats, each with two men, the daily catches being taken to a parent vessel to be split and salted down. Hand-lines are used occasionally, but the more usual practice is the employment of the "trawl," which is a long line, a mile or more in length, supported at one end by a small cask or similar buoy, and carrying at intervals of six feet a number of short lines of about three feet in length hooked and baited with pieces of frozen herring.

In some fishing areas line fishing is carried out by lines dragged through the water by a slow-moving vessel.

**Problems of the Fishing Industries.**—The chief problems of the commercial fishing industries centre around the arbitrary fluctuations in the numbers of fishes that are caught. That is to say, they are problems of scarcity and glut. The difficulty of deciding whether a scarcity, in the numbers of marketable individuals of any particular food fish, arises from natural causes outside the control of man, or whether such scarcity arises from artificial factors which can be controlled, is particularly acute in the case of an industry such as fishing where the annual statistics of catches landed cannot, owing to the interference of other factors concerning markets' demand, efficiency of gear, labour troubles, and so forth, be considered accurately to represent the variations in occurrence of marketable fishes over a period of years.

That there exists an irregular fluctuation in the annual abundance of available food fishes is of course undeniable.

The occurrence of "rich and poor years" has already been remarked upon in the case of the Ceylon pearl oyster. Similar fluctuations have always characterised the herring fishery. It seems almost indisputable that fluctuations in the appearance and numbers of extremely migratory fishes such as cod and herring, are bound up intimately with variations in the appearance of plankton, and so indirectly with variations in the annual or cyclical movements of temperatures and currents, and are not produced to any serious extent by local agencies. The productiveness of fish is influenced to such a great extent by widespread climatic fluctuations that it may be regarded as independent of the interference of man. The conclusions derivable from the results of modern fishery research seem to show that the fluctuations in the numbers of Clupeoid and most Gadid fishes, at any rate, are not affected by the intensity nor by the methods of fishing.

On the other hand, however, fishing methods would appear

in certain waters to have reduced considerably the numbers of plaice and haddock.

It is of course only to be expected that a virgin fishing ground, abounding in large and aged flat-fishes, will show after a period of intensive trawling a reduction in the average size and age of the fishes captured. That is to say, intensive steam trawling can reduce the number of exceptionally large and aged flat-fishes that occur in an undisturbed fishing area.

Recent exploitation of the Iceland Banks seems indicative of this. It would not appear justifiable, however, to attribute altogether to intensive steam trawling the gradual diminution in size and numbers of marketable flat-fishes from the North Sea Banks during the years prior to the Great War, since there is undoubtedly an enormous mortality of larval and immature food fishes in inshore waters through the operations of coastal fishery methods and through predatory birds and fishes.

At the same time it must be remembered that fishery research tends more and more to show that the more important kinds of fishes, especially the plaice and haddock, are always receiving enormous accessions of young individuals and that, as the Danish scientist Petersen has maintained and demonstrated, proposals for preserving the fish supply should aim rather at the protection of older fishes than of the young year classes.

The cessation of fishing in the North Sea caused by the war undoubtedly gave the flat-fish population a great chance of recuperation.

This contention seems supported by the marked improvement in the numbers of marketable sizes of North Sea flat-fish during the last few years. During the war there was almost a complete cessation of bank trawling in the North Sea, but the amount of inshore fishing and consequent mortality of young fishes were probably not greatly affected. That this recuperation of the North Sea Banks has resulted from the restriction of fishing during the war years seems to admit of little doubt. That is to say, the value of fishery replenishment by the liberation of young fishes bred in coastal hatcheries is doubtful, and legal restrictions concerning the prohibition of inshore trawling, the enforced use of definite sizes of mesh, the prohibition of the sale of undersized fish, the closure of areas, and so on, probably make little difference to the numbers of marketable flat-fishes. So long as intensive trawling continues, since any restriction of trawling activity is uneconomic and impracticable, the diminution in numbers of marketable sizes of flat-fishes upon the present

fishing banks is inevitable. It can only be met by the exploitation of virgin areas, and by developing a market for kinds of fishes which at present are plentiful but unmarketable, owing largely to the caprice of custom.

The small species of shark which are comprised under the colloquial terms of dog-fish and cat-fish were, for example, almost unsaleable before the war, despite the fact that they are excellent food fishes.

The increased prices, however, of haddock and plaice forced the British fish-frying trade to experiment with other food fishes, and dog-fish and cat-fish are now extensively marketed and consumed as "white salmon."

The wastage and confusion caused by a temporary glut of food fish catches has been minimised very considerably in recent years by a better organisation of rail transport and of marketing facilities; by improvements of fish preservation methods; by the establishment of curing and canning industries; by the establishment of fish meal factories, and so on.

# CHAPTER XXX

## WHALING AND SEALING

**The Whaling Industry.**—The order of mammals termed *Cetacea* or whales comprise two somewhat different groups of animals, namely, the **whalebone whales** (*Mystacoceti*), which lack teeth and in which the palate carries two longitudinal series of transverse horny plates with fringed edges, and the **toothed whales** (*Odontoceti*), in which calcified teeth are always present after birth. The whalebone whales, from the point of view of commercial exploitation, comprise :—

(*a*) **Right whales** (*Balæna*) with smooth throat and no dorsal fin, comprising particularly the Greenland whale (*B. mysticetus*), the Biscayan whale (*B. biscayensis*), or Nordcaper, and the Southern whale (*B. australis*) with several varieties.

(*b*) **Humpback whales** (*Megaptera*) with plicated throat, low hump-like dorsal fin, and long fore flippers ; they include particularly *Megaptera böops*, the Humpback.

(*c*) **Rorquals** (*Balænoptera*) with plicated throat, small forelimbs, and slender shape ; they are active whales and include the Blue Whale (*B. sibbaldi*), the largest living creature, the Finner (*B. musculus*), the commonest whale of British coasts, and Rudolphi's Rorqual or the Sei Whale (*B. borealis*).

The *Odontoceti* include the Sperm Whale (*Physeter macrocephalus*) or Cachalot, one of the largest creatures, the Bottle Nose (*Hyperöodon rostratus*), the various species of small whales popularly termed porpoises and dolphins, and the narwhal.

The chief commercial products supplied by the whaling industry are :—

**Oil,** which is obtained by boiling every part of the animal except the whalebone or the teeth for twenty-four hours under steam pressure. The lower grade oils are used chiefly for soft soap manufacture, but the neutral, odourless, fatty substance which occurs in the head of the sperm whale, and is termed spermaceti, is used in the manufacture of candles. The bulk of the whale oil is obtained from the **blubber,** a layer of fat, twelve to eighteen inches thick and of the consistency of hog's

lard, which lies immediately underneath the skin and yields, on boiling, its own weight of thick, viscid "train oil."

**Whalebone,** the horny substance which occurs in thick parallel plates attached to the upper jawbones and was, during the crinoline epoch of ladies' fashions, the chief product for which whales were hunted; its use has declined considerably and is now limited chiefly to the preparation of certain stiff silk fabrics, the baleen being shredded and mixed with the carded silk.

Products of lesser importance are the **meat,** usually dried and ground for cattle food, but canned by some United States factories for human food.

**Bone meal**; and **ambergris,** a fatty secretion from the intestines of the sperm whale, much used as a diluent for perfumes. Ambergris is rare and thus of very considerable value.

The history of the whaling industry may be said to comprise four phases, each of which was marked by the abundance of some particular kind of whale, and each of which declined as the object became scarcer.

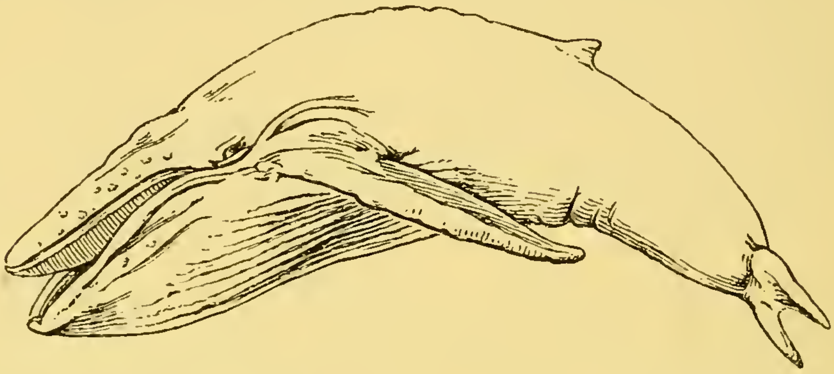
The first of these phases lasted probably from the eleventh to the sixteenth century, and had as its chief object the Nordcaper (*Balœna biscayensis*). This whale was hunted originally by the people of the Bay of Biscay, Basques chiefly, probably in inshore waters at first but later as far afield as the Norwegian coast or even possibly the coast of Newfoundland.

The second great whale fishing phase centred round the Greenland Right Whale (*Balœna mysticetus*). The fishing was carried out in the sixteenth and seventeenth centuries chiefly by English and Dutch ships, and to a lesser extent the Danes and French, and in the early eighteenth century by the New England whalers. There was continual friction and quarrelling between the different nationalities. The fishery was at first an inshore fishery along the coast of Spitzbergen, but in 1623 this bay fishery was exhausted, and whaling ships began to exploit the waters between Spitzbergen and Greenland, and afterwards fished in the waters of Davis Strait and Baffin Bay. Then from about 1820-80 the Greenland Right Whale was hunted by United States whalers in the extreme North Pacific and adjacent parts of the Arctic Ocean. By the end of the nineteenth century this whale was almost extinct in all three of the regions where it formerly flourished.

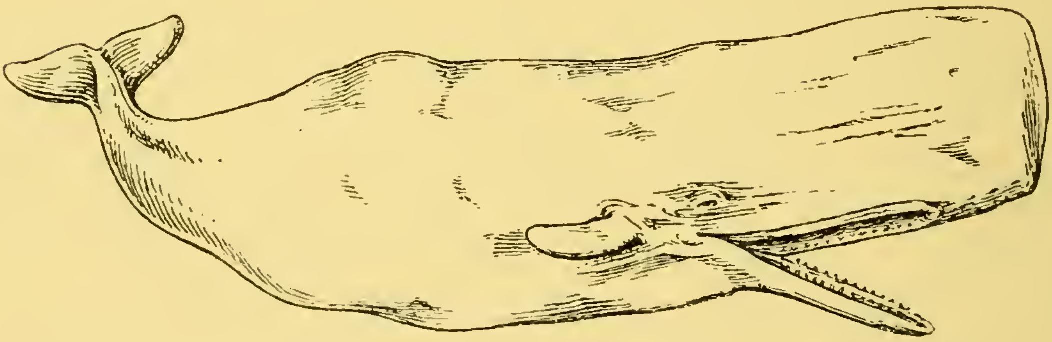
The third phase of the industry was the so-called Southern Fishery of the British, the Pacific Fishery of British and American

whalers, and its chief object was the Sperm Whale. This phase commenced about the middle of the eighteenth century and lasted about 100 years. The fishery was conducted off the coasts of Chili, Peru, and California, in various parts of the

Blue Rorqual (*Balænoptera sibbaldi*). (After Lydekker.)



Humpback Whale (*Megaptera böops*). (After Lydekker.)



Sperm Whale (*Physeter macrocephalus*). (After Daniels.)

North Atlantic Black Right Whale (*Balæna glacialis*). (After Lydekker.)

Fig. 49.—Types of Whales.

Pacific around the Galapagos and Marquesas Islands, in the Indian and China Seas, particularly around the Island of Timor. In addition to the sperm whale, the Southern Right Whale (*Balæna australis*) and the Elephant Seal were also hunted. The American whalers alone between 1804 and 1817 captured 193,522 Southern Right Whales.

Many of the American whalers of the fifties and sixties of the nineteenth century used Honolulu as a base, and from there fitted out in March for a summer season in the Behring Sea and the Sea of Okhotsk, and in November for a winter season in tropical and sub-tropical waters. This sperm whale phase of whale fishing lingered up to the beginning of the present century. So late as 1898 there were no less than twenty-nine whaling companies working at the Azores, and this whale is by no means extinct yet, a few individuals being captured every year.

Now from the early days of whaling until about 1880, methods did not change greatly in principle. Strongly built sailing vessels, chiefly of the brig and schooner type, were used and were provisioned for a three years' cruise. The ship was provided with four to six boats, about twenty-seven feet long by four feet wide, known as whale boats. When the prey was sighted, these boats were lowered and went in pursuit. The whale was lanced by one or more harpoons, six foot wooden lances, each with a loose steel head to which a long line was attached. The line was long enough to allow for the stricken whale diving to a great depth. These boats were towed hither and thither by the dying animal until it could be given the *coup de grace*, towed to the parent ship, and roughly stripped of blubber and whalebone. The blubber was rendered down after the ship returned to the home port.

Obviously with such crude fishing methods, no attempt could be made to utilise the active rorqual type of whale, nor was it worth while to kill whales less than forty feet long. There was, in addition, an enormous wastage of whale products.

The fourth and present-day phase of whale hunting may be said to have been ushered in by the adoption of the harpoon gun about 1880.

The term harpoon gun is somewhat of a misnomer, the apparatus being really a sort of explosive bomb attached to a line and fired from a gun fixed in the bows of a small steamer. This gun has rendered possible the capture of the smaller and more active species of whale in such numbers that their small weight of oil is made up for by the quantity of whales secured. Further, many of these Finners and Rorquals can be captured fairly near land and can thus be towed ashore to a factory, where the whale can be completely utilised.

Modern whaling is almost entirely carried on by Norwegian companies working from coastal bases with small steamers. In northern waters such bases occur in Iceland, the Faroes,

the Hebrides, and the Shetlands. The whales captured are chiefly the common Finner (*Balænoptera musculus*) which follows the herring shoals inshore, the Sei whale (*Balænoptera borealis*), and occasional Sperm, Blue, Bottlenose, Humpback, and Nordcaper whales. Similar bases occur in southern waters in South Georgia, Kerguelen, the South Shetlands, the South Orkneys, and the Falklands.

A certain amount of whaling is carried out also in the Behring Sea, off the Australian coast, the coasts of Chile, West Africa, East Africa, and North Japan. The majority of whales killed in southern waters are Humpbacks.

There can be little doubt that owing to the gradual decline in the numbers of whales, and owing to the competition of vegetable oils with whale oil in the markets, the whaling industry is a decaying one, so that schemes for the preservation of the whales yet remaining will probably in the future be scarcely necessary. The extinction of finners in any case seems hardly possible, although their numbers are diminishing rapidly. Right whales and sperm whales are already too scarce to be worth the fitting out of vessels for their capture. In any case, under modern conditions, when the number of whales captured per steamer falls below a minimum number, whaling in that locality must be abandoned, and the whales would presumably have a chance to recuperate.

Such recovery, however, is slow, and whales are not as a rule locally restricted in distribution, so that any increase in numbers is not readily apparent. Past experience has shown that once the numbers of a particular species of whale begin to diminish, no amelioration measures have yet succeeded in bringing about an increase.

There can be no doubt, therefore, that if only for the sake of the industry itself, whaling should be restricted. Measures towards this end, which have been suggested and in some cases put into operation, comprise : annual licensing of whaling steamers ; prohibition of whaling in territorial waters ; prohibition of whaling during herring fishing seasons; establishment of closed seasons ; protection of whales accompanied by calves.

The closing of overfished areas is apparently impracticable, owing to the vast area over which most species of whale are known to range. The protection also of gravid females is also out of the question, since it is impossible to distinguish such females from the others when swimming.

**The Sealing Industry.**—The term " seal " will be used in this chapter in the commercial sense as applying to members

of three distinct families of aquatic carnivorous mammals, namely, the **Sea Lions** (*Otariidæ*), the **Walrus family** (*Trichechidæ*), and the **true Seals** (*Phocidæ*).

These animals agree in being adapted to a partially aquatic mode of life. Thus their shape is fish-like and their hands and feet are webbed.

The sea lions are the least modified in this respect, since their hind limbs are still capable of assisting the animal to shuffle about on land, the external ear, though small, is present, and the nostrils are at the end of the snout as in terrestrial animals.

The walrus can progress on land like a sea lion, but there are no external ears.

The seals have the hind limbs bound up with the tail and quite useless for progression on land; they have no external ears; and the nostrils are quite dorsal in position, as in other aquatic animals such as whales and crocodiles.

Of the *Otariidæ*, two genera, namely *Callorhinus* and *Arctocephalus*, are generally referred to as **fur seals.** The remaining genera may be termed sea lions.

**Callorhinus** is the fur seal of the North Pacific waters and comprises *C. alaskanus* of the Pribylov Islands, *C. ursinus* of the Commander Islands, and *C. curilensis* of Robben Island.

**Arctocephalus** is the fur seal of the Southern Pacific waters, and comprises *A. townsendii* of Guadaloupe, and *A. philippii* of Juan Fernandez, the coast of Chile, the Galapagos, etc., both genera being now, from a commercial standpoint, extinct. *A. australis* occurs off the coast of South America from Brazil and Chile downwards, the Falkland Islands, Tierra del Fuego, and South Georgia. *A. delalandi* inhabits the shores and islands of South-west Africa, and Tristan da Cunha.

*A. gazella* inhabits Kerguelen, St Paul and Amsterdam Islands, and is protected by the Government of New Zealand.

Of the true **sea lions,** Steller's sea lion (*Eumetopias stelleri*) inhabits the Pacific between Behring Strait and California; the Californian sea lion (*Zalophus californianus*) ranges from lower California to San Francisco; the Southern sea lion (*Otaria byronia*) ranges along the western coast of South America as far south as the Falkland Islands; the Auckland sea lion (*Phoarctos hookeri*) inhabits the Auckland Islands; the Gray sea lion (*Zalophus lobatus*) inhabits the coastal waters of Australia and New Zealand.

The habitat of sea lions is usually small coastal islands, on which the young are reared and from which the adults take

long trips out to sea. The food, judging from an examination of stomachs of sea lions along the western American coast,

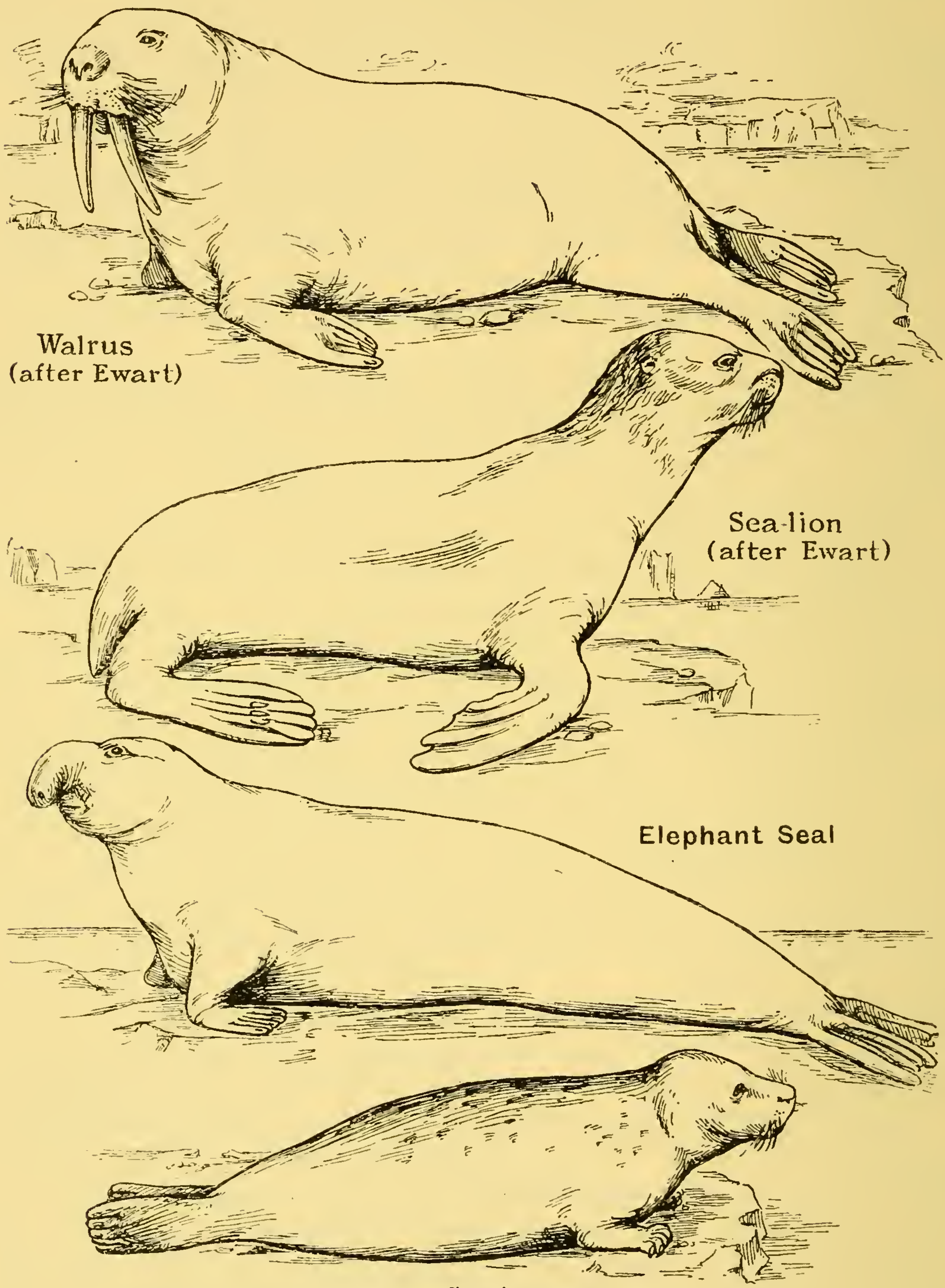



Fig. 50.—Types of Seals and Sea Lions. (Not to scale.)

seems to be chiefly squid or other cuttle-fish, in spite of the large quantities of rock cod, salmon, and other fishes in the vicinity of the sea lion rookeries.

The **walrus** (*Odobenus*) is Arctic and circumpolar, and is characterised by the enormous canine tusks of the upper jaw, by the help of which the animal digs up the shellfish and crustacea on which it feeds, and by the help of which it clambers from the water on to the ice floes on which it rests.

The **seals** include a number of commercially important species.

The commonest species is *Phoca vitulina*, four to five feet in length, the coastal or **Harbour Seal** of Arctic, North Pacific, American, and North European shores ; on some coasts this seal is becoming comparatively rare owing to persecution by fishermen who consider, rightly or wrongly, that this seal takes an undue share of food fishes.

The **Ringed Seal** (*Phoca hispida*) is a circumpolar species of very great importance as the main source of food for Eskimo tribes.

Occurring with this seal, in the southern part of its range, is the Greenland or **Harp Seal** (*Phoca grœnlandica*) with its harp-shaped black bar on the back of the males ; this is the most important, economically, of the true seals.

Along with the Harp seal occurs the **Hooded Seal** (*Cystophora cristata*) of the Greenland coasts, the male of which has a peculiar inflatable bag on the muzzle.

In Antarctic waters occur the **Leopard Seal** (*Ogmorhinus leptonyx*), the **Ross Seal** (*Ommatophoca rossi*), and the **Crab-eating Seal** (*Lobosa carcinophaga*), the first of which preys chiefly upon penguins.

In tropical waters, an exceptional habitat for seals, occur species of the genus *Monachus*, notably the **Caribbean Seal** (*Monachus tropicalis*), the first animal to be described from the New World, having been noted on the second voyage of Columbus in 1494.

The **Monk Seal** (*Monachus monachus*) inhabits the Mediterranean and Adriatic and Black Seas.

The largest of the seal family are the **Elephant Seals** (*Mirounga*), with two species, the Guadaloupe or Northern Elephant Seal (*M. angustirostris*) and the Kerguelen or Southern Elephant Seal (*M. leoninus*).

These animals are gigantic, reaching a length of twenty feet, and the males possess a ten-inch trunk or proboscis at the end of the snout. This trunk, despite the statements of earlier observers, cannot, according to Townsend, be inflated as can the trunk of *Cystophora*, but can be drawn back by muscular action to form a series of heavy folds on top of the head.

**Commercial Value of Seals.**—Seals are hunted commercially either for their pelts or for their oil.

The finest sealskins have always been obtained from certain islands in the North Pacific Ocean, notably St Paul and St George, Pribylov Islands, Copper Island, Robben Islands, and the islands of North Japan. Other species of fur seal occur in the South Pacific and South Atlantic around Cape Horn, the Falkland Islands, up to Lobos Island at the entrance of the River Plate, off the Cape of Good Hope, and the Crozet Islands; but only the pick of the Lobos Island skins come anywhere near the quality of northern sealskins.

When Alaska and the Aleutian Islands were purchased from Russia by the United States Government in 1867 for seven million dollars (£1,400,000), the value of the fur seal pelt was scarcely known or appreciated. The activities of Russian fur hunters had been concentrated on the sea otter. On St George and St Paul the number of seals in 1872-73 was estimated at three to four millions. In 1870, the islands were leased to the Alaska Commercial Company for twenty years, not more than 100,000 seals per year to be killed. A vigorous advertising campaign undertaken by this company in London brought sealskin into great popularity, and the value of skins rose accordingly. The result was that hordes of poachers were attracted to the seal area, and by 1880, by the so-called "pelagic sealing" methods, namely the use of long range rifles fired from ships, poachers were capturing more seals then the company, whose annual catch had fallen to 8,400.

The habits of the seal are peculiarly favourable to this method of destruction. From September to May the animal is almost wholly aquatic, cruising in a 6,000 mile circuit from Alaska to the Californian coast and northwards to the Aleutian Islands, where during the first fortnight in May the seals land, the young are born, and the surplus males fight fiercely for the privilege of a harem of six to ten females. The young remain on the islands until October, the parents putting out to sea daily and returning at night.

It is during this period that the method of pelagic sealing was bound to inflict enormous damage. Such a method allowed of no discrimination between the superfluous male and a female seal with one or two pups to support. In the dense fogs, too, which occur frequently around these islands, poachers were able to evade the patrol vessels, to land on the islands, and to club and hurriedly skin hundreds of seals, the skinning of seals which were only stunned being a common occurrence.

In spite of patrols, in spite of the closing of the Behring Sea, pelagic sealing continued and the number of seals steadily diminished. In 1895, almost 60,000 sealskins were marketed by poaching vessels, as against 15,000 taken legally by the North American Company which had succeeded the Alaska Company, and some 30,000 pups were estimated to have perished of starvation. In 1910, the total number of living seals probably did not exceed 200,000. Then an extensive campaign of propaganda was instituted, chiefly at the instigation of the American naturalist Hornaday, supported by the Camp Fire Clubs of the United States. Pressure upon the Government brought about an international treaty in 1911 between Japan, Russia, Great Britain, and the United States, and sealing became a monopoly of the United States, compensation being arranged for with other countries concerned. Pelagic sealing was stopped. A close season of five years was declared. To protect the females and young, however, it has been necessary to kill a certain number of surplus males each year. The result has been quite successful, the estimated number of seals in 1918 being 496,432, and in a few years time the annual surplus of male seals should be as high as 100,000, and there will be no loss of females nor young.

It may be added that it has been definitely ascertained that the principal food of the fur seal is not fish, and that the same may be true with regard to the other sea lion, Steller's sea lion (*Eumetopias stelleri*) of the same region, despite the statements made by salmon canning interests in that area. At any rate the Federal Department of Fisheries of the United States Government has refused to sanction the indiscriminate and promiscuous killing of this sea lion.

The present demand for fur of any sort has stimulated the commercial hunting of the **Harp Seal** off the coasts of Newfoundland, although its coat cannot compare in quality with that of the true Fur Seal.

This species at breeding time assembles on the ice floes, and drifts southwards to be clubbed in thousands during the summer by the Newfoundland sealers. Sealing is impossible on these coasts in winter, or this seal would have been exterminated long ago. As it is, however, an average of 125,000 seals are taken yearly, the smallest catch on record being just under 34,000 and the largest 350,000.

The newly-born seal has a white coat of thick woolly fur, and is termed a "white coat"; at the end of two weeks this coat is shed and the colour of the animal is steel-grey; it is

termed a " grey coat " ; from one to three years old the coat is spotted and the hair short ; this animal is termed a " bedlamer," a corruption of the French *bête de la mer*.

The pelts of white coats and grey coats are placed on the fur markets ; the skins of bedlamers and old seals are commercially valuable for the manufacture of belts, pocket books, and so forth ; the fat or blubber can be reduced to a tasteless clear oil which is valuable for many purposes.

The value of large seals has brought about the almost complete extinction of many forms.

Thus the sea elephants were almost extinguished by the middle of the last century by sealers and whalers for their oil and hides, although a few of the southern species survive on Kerguelen Island, and a few of the northern forms survive on the Island of Guadaloupe, now a Mexican Government reservation, which lies in the Pacific Ocean, 140 miles from the northern part of the peninsula of Lower California.

Similarly, the Caribbean seal (*Monachus tropicalis*) has been almost exterminated by sealers for its oil and hide.

The southern fur seals were ruthlessly and wastefully slaughtered by American sealers long before the Antarctic was charted, the only protected breeding grounds of these seals being Lobos Island in the La Plata, belonging to the Argentine Republic, which yields several thousand skins yearly. The Guadaloupe fur seal (*Arctocephalus townsendi*) has not been seen since 1894. In the case of the Alaska fur seal, only timely conservation measures saved it from a similar fate.

# CHAPTER XXXI

## FUR-BEARING ANIMALS

The greater bulk of the world's supply of furs originates from areas north of the fiftieth parallel north. A considerable number of rabbit, kangaroo, fox, wallaby, wombat, and opossum skins come from Australia ; South America sends pelts of the coypu rat, chinchilla, vicuna, kit fox, and raccoon ; the bulk of the trade, however, is based on skins from Alaska, Northern Canada, and Siberia.

That is to say, the greatest quantities of choice furs come from areas which are cold, damp, and well wooded. For this there are very definite reasons.

The type of mammal whose pelt is suitable for the fur trade has two kinds of hairy covering. There is an overcoat of long, stiff **overhairs** and an undercoat of short, thick, soft, and somewhat silky hairs—the **pelage** or **fur**. The pelage hairs are barbed, and so can be felted ; in the living animal felting does not occur, as the pelage is protected by the overhairs. In a prime skin the pelage is not visible unless the overhairs are blown apart, the overhairs being particularly dense and long in animals which lie out in the open exposed to severe weather. In fox skins, for example, they are between three and six inches in length. Strictly speaking, therefore, the term *fur* implies the undercoat, as in the prepared skins of seal and beaver where the coarse upper hairs have been removed ; but the term is applied popularly to skins where the overhairs are allowed to remain, such as fox, sable, mink, or skunk.

Now both overhairs and pelage are longest and thickest in animals exposed to intensely cold or intensely damp conditions. Aquatic animals such as seals, beavers, coypu rats, and musk-rats have very close and thick pelage but somewhat coarse, unbeautiful overhairs. Dry cold seems to stimulate the growth of overhairs. The shade of dense forests apparently develops a lustre or sheen upon the overhairs. Tropical or sub-tropical mammals have little or no pelage and have somewhat short or brittle overhairs, unless their habitat is of high altitude.

**Fur-bearing Animals.**—The more important types of furs

are drawn mainly from two families of mammals, namely the *Mustelidæ* or weasel family and the *Canidæ* or fox family;

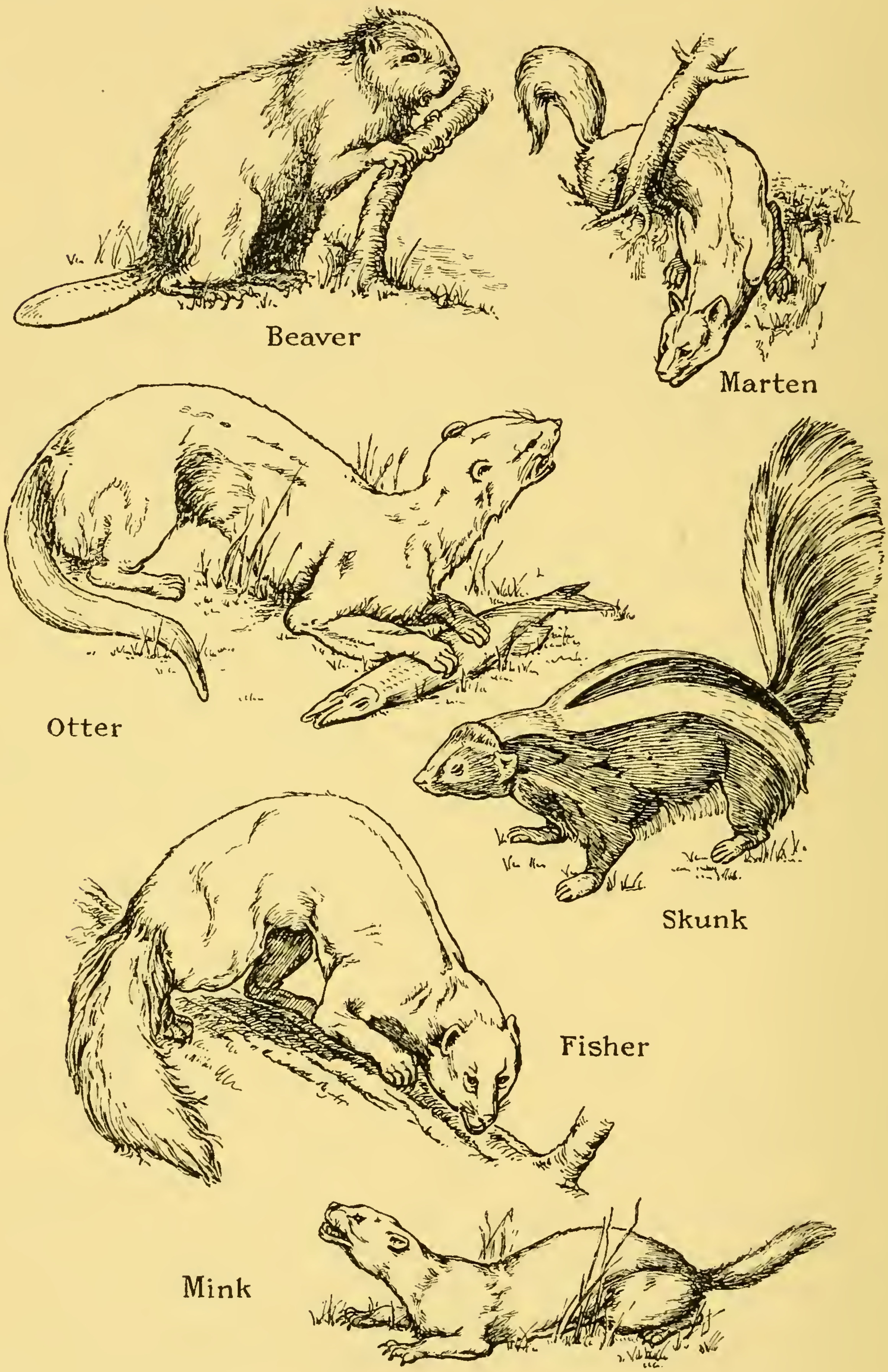



FIG. 51.—Types of Fur-bearing Animals. (After Hornaday.) (Not to scale.)

from certain other Carnivora, notably the otter and skunk; and from certain rodents, notably the beaver, coypu rat, squirrel, musk-rat, and rabbit.

The **Mustelidæ** is a sub-family of carnivorous mammals, popularly termed martens, polecats, and weasels, and limited in distribution to the temperate regions of North America, Europe, and Asia. There are about sixteen species, varying in size and colour, but similar in habits, being arboreal frequenters of woods and rocky places, their snake-like bodies giving them great grace and agility of movement; they are intensely blood-thirsty and feed chiefly upon small birds and eggs, and upon small mammals of the mouse-like types. The family may be divided into four groups of species—the martens, minks, polecats, weasels, and stoats (Fig. 51).

The choicest fur bearer of the Mustelidæ is undoubtedly the **Sable**, one of the marten group. The true sable (*Mustelus zibellina*) is a native of Russia and North China, the finest specimens coming from the Okhotsk district of Siberia. After the sable, the choicest member of the family is the **Fisher** or Pekan (*Mustelus pennanti*), a North American animal about the size of a cat, with a bushy tail, and of a greyish-black colour. The great standby, however, of the fur trade is the **American Mink** (*Mustelus vison*), some 600,000 of which are estimated to be captured annually. The animal somewhat resembles a long, thin rat with brown fur and a hairy tail, and is about two feet long. The fur is close, strong, and of great durability, and is of an amber-brown colour, darker and glossier on the back. The dyers usually accentuate the colour by brush dyeing. The animal extends over a large portion of North America, the finest specimens, however, coming from Quebec and the maritime provinces of Canada. The animal haunts the banks of streams, swims freely, and lives chiefly on fish and musk-rats.

The European or **Marsh Mink** (*Mustelus lutreola*) does not fetch the price of the Canadian species, but the Siberian Mink has become very popular under the name of **Kolinsky**, and is particularly prevalent in the Kola district of Siberia. The finest specimens come from Kusnetsk, the largest quantity from Yakutsk. The animal is about eighteen inches long, almost orange in colour, and has therefore to be dyed. A good skin, well dyed, will pass almost for sable. The rest of the Mustelidæ are rated less highly. The **Ermine**, which is the winter phase of the Stoat (*M. erminea*), no longer fetches the fabulous prices that were given in the eighteenth century. Most of the present-day ermine is derived from the American Short-tailed Weasel (*M. cicognanti Bonaparte*).

Very closely allied to the martens and weasels, though not

actually members of the same sub-family, are two animals whose fur value is sufficiently important to merit attention here ; they are the Otter (*Lutra*) and the Skunk (*Mephitis*).

**Otter** skin has always been regarded as a desirable and valuable fur. Of the many species of otter ranging over the northern hemisphere, the largest and most valuable from a fur value standpoint is the Canadian otter (*Lutra canadensis*), whose sub-species range from Labrador to Alaska, from Florida to the Arctic. Advancing civilisation, however, has driven the otter from his southern haunts, and the majority of American skins come from Labrador, particularly the district of East Main, Athabasca, the Rocky Mountains, and Alaska. The mode of life is uniform for all sub-species, and little variation in size or quality of the pelts is to be noted, although the pelts from Labrador and Newfoundland are somewhat darker, those from British Columbia somewhat larger, than in the case of other sub-species. The animal is semi-aquatic, living chiefly upon fish, and is about a yard in length. The pelage, as is usually the case in aquatic animals, is very close and deep and of a mahogany brown colour; the overhairs are long and coarse, and somewhat darker in shade than the pelage.

Otter is probably the most durable of all furs, but being somewhat heavy is suitable for countries where long cold winters are the rule.

Before the Great War, Canada and Russia provided the best markets, and something like 30,000 pelts a year were placed on the market, chiefly from Canada and Kamschatka. Since then the annual number has steadily dwindled, and the price, in spite of the closure of the Russian market, has steadily advanced, until otter now ranks in value only after sable, marten, mink, chinchilla, and mole.

The **Skunk** (*Mephitis*) is purely American in distribution, its several species ranging from Southern Canada to Central America ; very few come from Alaska and Labrador. The common species is *M. mephitica*, which is about the size of a cat, possesses a bushy tail about twelve to eighteen inches in length, generally carried erect, and a coat of stiff black hairs with a dorsal V-shaped white stripe, the point of the V being just behind the head. The animal is a burrower and feeds largely on insects, particularly grasshoppers, on mice, and even on poultry when obtainable.

It is exceptionally fearless, and with good reason, since scarcely any other animal will run the risk of receiving in its eyes a blinding spray of fœtid fluid from the skunk's anal glands.

Thirty years ago skunk fur had scarcely any market value. Better methods of dressing and deodorising the skin, however increased its value, but for a long time the skin had to be sold under an assumed name, black marten or Alaska sable. The pelts, however, are to-day in eager demand under their true name, and skunk fur is even imitated. The annual catch of skunks is estimated at a million and a half, and is far short of the demand. The skins are graded in value according to the sizes of the white stripe. Grade I. pelts are jet black with small white patches behind the neck ; Grade II. have the white V as far as the shoulders ; in Grade III. the V extends along the back, but the stripe is narrow ; in Grade IV. the stripe is wide. The white parts of the skins are machine sewn into strips or plates and dyed black.

A smaller species of skunk, the Little Spotted Skunk (*M. interrupta*), is also trapped for fur, but the pelt is known commercially as **civet**.

**The Foxes.**—Next in value after the mustelid fur bearers, in aggregate value at any rate, ranks the group of fox species.

The fox is one of the most widely distributed animals in the world. Few areas of the world, whether arctic, temperate, or tropical, are without some species of fox. There are foxes in the remotest deserts of Africa and Asia, foxes in the inhospitable wastes of the Arctic, foxes in the vicinity of industrial cities in civilised Europe and America. From a fur value standpoint, however, only such foxes as inhabit North America and Northern Eurasia need be considered, and of these only the following examples :—

The **Common Fox** (*Canis vulpes*) of Europe and Asia ; the North American **Red Fox** (*C. fulvus*) ; the **Kitt Fox** (*C. velox*) of North America ; the **Grey Fox** (*Urocyon cinereus*) of the Southern United States ; and the **Arctic Fox** (*Canis lagopus*). The Asiatic, African, and South American species are, except for Alpine varieties, poorly furred.

The Common Fox is widely distributed across Europe and Asia. There are few animals more variable in size and colouring than a fox, few animals more puzzling to a taxonomist, and the Common Fox is no exception to this.

There are a large number of sub-species or varieties. The colour may vary through many shades of red and grey. The fur is not of great commercial value individually, but in the aggregate has considerable value, for some hundreds of thousands are trapped annually in Scandinavian, German, and Russian districts, and used not only for home use but for

exportation to the United States, although the quality is inferior to that of American foxes.

The American Red Fox may represent merely some ten American sub-species of *Canis vulpes*, but seems more likely to be a separate species (*Canis fulvus*) subdivided into ten sub-species, since its range is not confined to North America but extends into China and Siberia. In North America its extreme southerly range is probably North Carolina, Tennessee, and Pennsylvania; in the southern states its place is taken somewhat by the Grey Fox.

The general colour ranges from yellow to a deep red, the Kamschatka varieties being particularly deep in colour. The finest skins are probably those from the Esquimau district of Labrador.

There are two colour varieties which, owing to their beauty and scarcity, fetch very high prices. These are :—

(*a*) The **Silver Fox** or Black Fox, which at its finest is jet black with a white tail tip, but may have silver hairs scattered among the black ones. There is no trace of red.

(*b*) The **Cross Fox**, which is a partially melanistic variety, the black or silver hairs being present on back and shoulders, so as to give the appearance of a cross, the sides, neck, and ears being yellowish.

The Kit Fox (*Canis velox*) or Swift Fox ranges from Saskatchewan southwards through the Great Plains to New Mexico, where it overlaps with the Californian and Texan foxes (*V. nacrotes*, *V. multicus*, *V. arsipus*).

It is typically a prairie animal, is no larger than a house cat, and of a yellowish ground colour with silver-grey overhairs on back, overlying a grey-brown under fur.

The Grey Fox (*Urocyon cinereus*) or Virginian Fox of California, Texas, and Mexico is in less demand than the foxes described above, the fur being very much coarser.

The Arctic Fox (*Canis lagopus*) is circumpolar in range. There are two varieties. In the extreme north the colour is white in winter and brown in summer (the so-called "stone fox"). In more southerly latitudes, such as Greenland and Alaska, the animal is a grey ash or bluish-brown colour all the year round, and is known as the "blue fox." It must be emphasised that the Blue Fox is not, therefore, the summer phase of the White Fox; it is quite a distinct variety of *Canis lagopus*. This variety is distinctly rarer than the white and fetches higher prices.

Statistics as to the number of fox skins that pass through

the fur dealers' hands annually are difficult to come by. Emil Brass, a German commercial agent who for many years compiled fur trade statistics, estimated an annual number of 2,952,300, a figure based on the period 1907-09, and divisible as follows :—

| Source. | Red. | Cross. | Silver. | Kit. | Grey. | White. | Blue. |
|---|---|---|---|---|---|---|---|
| Europe . | 775,000 | ... | ... | ... | ... | 5,000 | 1,000 |
| America . | 200,000 | 15,000 | 4,000 | 4,000 | 50,000 | 30,000 | 6,000 |
| Asia . . | 160,000 | 3,000 | 300 | 60,000 | ... | 70,000 | 4,000 |
| Australia . | 30,000 | ... | ... | ... | ... | ... | ... |

Along with some 260,000 skins of raccoon dog from Japan and Mongolia, and some 15,000 skins of South American foxes.

Fur trade statistics are notoriously untrustworthy, however, the number of skins that figure in auction sale lists in any year rarely corresponding to the actual number of animals caught, since skins unsold at one auction may appear subsequently at another auction. During the period 1820-1905, the Hudsons Bay Company collected 1,536,420 skins of Red Fox, in all probability the true American red fox, which is a yearly average of 18,075. In the period 1820-91, the other American companies collected 3,831,516, an annual average of 53,965 ; a total annual average of American red foxes of 72,040 skins, which differs somewhat from Brass's estimate. In any case Brass's estimate is almost certainly too low for recent years.

**Other Fur Bearers.**—During the first 100 years of its history the American fur trade may be said to have depended largely upon the supply of fisher, marten, otter, mink, and beaver. Sealskin was hardly known before 1870. Beaver in particular was for a long time the staple fur of the American trade.

The American **beaver** (*Castor canadensis*) is the largest, with one exception, of that order of mammalia termed Rodentia, being in length from fourteen to thirty-two inches. It is a thoroughly aquatic animal, a feeder on soft barked trees (aspen, willow, poplar), and is extremely sociable, living in colonies of so-called "lodges," dome-shaped dwellings half submerged in water, and constructed of timber and mud.

As is usual with semi-aquatic mammals, the pelage is intensely close and soft, and was formerly in extensive demand for hats ; but since the beaver hat was ousted from popularity by the silk hat, the fur has been in request for coats, ties, and muffs. No animal did more than the beaver to effect the opening up of

North America. In search of beaver, trappers explored the remotest corners of North America, relied upon it for food and clothing, and exchanged the skins for the civilised products of Europe. Unfortunately, owing to its dependence upon well-watered and well-wooded country, the range of this interesting animal is rapidly restricted by agricultural settlement. In Europe the animal became practically extinct two centuries ago, although about 12,000 specimens exist in Southern Norway, along the River Nidelven, and in North America its extinction has been barely averted by national conservation measures. It is now limited in range to the Great Lakes, Labrador, around Hudson Bay, North Ontario, Athabasca, and British Columbia.

In 1907-08 Brass estimated the annual output of beaver as 80,000, a considerable reduction from the hundreds of thousands of skins that were shipped to Europe annually a hundred years before. In 1912 the annual catch was 17,000 and the beaver seemed doomed, but vigorous protective measures and the swing of the pendulum of fashion to fox and mink gave the animal a chance to recuperate. In the spring sales of 1920, for example, some 800,000 skins were again on offer.

The scarcity of beaver brought into vogue the pelt of the **Coypu Rat** (*Myopotamus*), an aquatic rodent from South America, whose skin, under the trade name of "nutria," is very similar, if inferior, to beaver.

The fur is not so thick and heavy as that of beaver, and is of a dull sepia brown as compared with the lustrous greyish-brown of beaver, and has to be dyed, a process which of course detracts from the value.

The beaver and coypu rat are not the only fur-bearing representatives of the rodents.

The **Musk-rat** (*Fiber zibethicus*) is a rodent about the size of a vole or meadow mouse, that is to say about eight to ten inches long. It is aquatic in habit, an inhabitant of the salt marches around Delaware and Chesapeake Bays of the Atlantic Coast of the United States, and the swamps in the Cumberland Lake region of the upper Saskatchewan river of Canada, and it feeds chiefly upon bulbous roots, wild rice, and wild lilies, but in some areas feeds upon mussels and carp. The burrows are either just above the water-line in the banks of streams, or in built-up nests in shallow water.

The living quarters are always well above water-line, the entrance below the water-line. The animals are very prolific, two or three litters of six to twenty being produced each year,

and sometimes five litters are produced. About ten million musk-rats are captured annually in Canada and the United States, and the supply shows very little sign of diminishing. The flesh and musk-bags are all saleable. The flesh is sold in large quantities in Baltimore and Washington as marsh hare.

The raw pelt is dense and soft, very much like beaver in appearance, but shorter and less close. The colour varies with the locality and season. Northern skins, though heaviest in fur, are lightest in colour, possibly because they are taken in summer pelage; very dark skins come from New Jersey, Delaware, and Maryland. The first demand for musk-rat was for the manufacture of so-called beaver hats, and when such hats went out of fashion the demand for musk-rat fell off. Then it became used for linings. Then improved methods of dressing and dyeing, and its use as "Hudson Bay Seal" increased its market value greatly, and in quantity it is now one of the biggest items in any fur auction.

The **Chinchilla**, a jumping mouse of the South American pampas (Chili, Bolivia, Peru), has a fur of great delicacy and of a dark blue-slate and pearly appearance. Its pelt brings very high prices. The **Viscacha** is a similar animal with a fur, however, larger, coarser, yellower than that of the chinchilla. The demand for chinchilla is met by 50,000-80,000 skins a year, although Bolivia in particular has declared a close season for some years.

Scarcity of chinchilla has given a stimulus to the production of mole skins, but the plentitude of these is offset somewhat by the expense and trouble of dressing them, so that comparatively high prices are necessitated for what is really common skin.

Another rodent with a fragile but beautiful fur is the **Squirrel**, of which enormous numbers (15,500,000 according to Brass) are marketed annually, the greater bulk being chiefly provided by Russia and dressed around Leipzig.

## CHAPTER XXXII

## THE FUR TRADE

The fur trade is one of the oldest industries in the world, since the prime article of barter between civilisation and savagery has generally been the animal skin. In the Middle Ages a considerable commercial intercourse went on between the natives of Scandinavia, of North Russia, and of Siberia and the fur traders of Nijni Novgorod, Moscow, and the Hanseatic ports of the Baltic. Venice and Genoa distributed these products of the European forests to the Mediterranean countries, to France, and probably to Great Britain. Furs were scarce and dear. Most countries regulated the supply by means of Sumptuary Laws. Thus in Great Britain, mediæval law restricted the wearing of furs to royalty, to the nobility, and to clerical dignitaries. Ermine was a prerogative of royalty, just as, up to quite recent times, the use of sea-otter fur was restricted in China to mandarins.

The history of modern commercial fur trading, however, may be divided, just as in the case of the whaling industry, into a number of phases. Unlike the latter industry, these phases have been influenced to a considerable extent by the vagaries of fashion.

The first phase was ushered in by the discovery of the vast animal resources of the North American forests, and was based upon the skin of the beaver, vast quantities of which were sent to Europe during the seventeenth and eighteenth centuries to supply the demand for beaver hats. The exploration of North America owes much to the fur trader.

Canada, after the French had been ousted, became the huge preserve of the "adventurers of England trading into Hudson Bay," who, by a charter granted in 1670 by Charles II. to his cousin Prince Rupert, acquired a monopoly which endured, apart from a hectic decade (1811-20) of competition with the North-Western Fur Company of Montreal, until 1859. The New England area was exploited by the Dutch West India Company, perhaps the earliest fur trading company of America, with posts at New Amsterdam (New York), Beaverwick

(Albany), along the Delaware, and along the coast of Maine. From 1621 onwards this company was sending 60,000 beaver skins annually to Europe.

The south-eastern area of the United States was exploited similarly by the Missouri Fur Company and the American Fur Company, both founded by an enterprising German fur trader named John Jacob Astor.

The emissaries of these various companies, the *voyageur* and the *coureur du bois*, followed the beaver through the swampy labyrinths and trackless forests of almost all North America.

Astor even founded a post at the mouth of the Columbia river, in spite of almost incredible difficulties, but later abandoned the scheme.

The raw pelts were sent by flotillas of boats from Ottawa down the St Lawrence to Montreal, or down the Mississippi and Missouri to St Louis, or they came from Winnipeg to St Paul in long trains of creaking ox wagons across the prairies. At St Paul or St Louis the furs were sorted and despatched to New Orleans, to New York, to London and Hamburg.

During the latter half of the seventeenth century some 40,000 skins, chiefly beaver, were sent to London alone every year. Twenty beaver skins was the price of a musket along the Mohawk river, but in more unsophisticated regions a musket was worth as many beaver skins as could be piled up, one on top of the other, to its height, and especially long barrelled muskets were imported. Values of goods all over North America were computed in beaver skins, the Hudsons Bay Company issuing a lead coinage stamped with 1B, ½B, ¼B, and with the district of issue—Y.F. (York Factory), E.M. (East Main), and so on—which was current all over Canada. Vast fortunes such as the Astors were founded almost entirely on beaver skins.

The second phase was brought about by the ousting of the beaver hat from popularity by the silk hat, and the adoption of ornamental fur garments as fashionable wear. It may be termed the phase of *choice furs*, since owing to the absence of technical methods of fur dyeing and shearing, only such furs as beaver, sable, otter, ermine, silver fox, sea otter, and chinchilla were acceptable. The choicest sable skins came always from Siberia and North China.

The third phase was that of *substitute furs*, and commenced about 1870 when the growing scarcity of sable brought on the market the American marten and fisher as substitutes. An advertising campaign about the same time, in London, brought

sealskins into fashion. Mink, used formerly as a coat lining, became a choice substitute for fisher and marten. Cross fox and blue fox replaced the scarce silver fox. Beaver became replaced by coypu ("nutria"). Persian lamb came into fashion.

The fourth and present phase is that of *imitation furs*. The growing scarcity and dearness even of substitute furs, and improved methods of dyeing and dressing, brought other kinds of furs into the market. Skunk, unsaleable as skunk, sold readily as Alaska Sable; musk-rat was dressed and dyed until almost indistinguishable from sealskin, and fetched good prices as Hudson Bay Seal; raccoon became fashionable as Silver Bear and Blue Fox; then came the later years of the Great War, and an enormous boom in furs, whose prices soared to fantastic heights. Almost any kind of skin could be sold as fur. Even the Hair Seal became sought after. Skunk, which could now be sold unashamedly under its own name, became fashionable and dear, and the humbler opossum became its handmaiden under the name of Skunk Opossum. Musk-rat, no longer under the necessity of masquerading under an assumed name, sold boldly as musk-rat or musquash. The rabbit came into its own. Millions found their way to America via California, were clipped, dyed and doctored, and appeared, and still appear, as Electric Seal, Coney Seal, Coney Beaver, Squirrel Coney; white hares masquerade now as White Foxes; grey foxes, dyed black and with the silver tipped hairs of badger glued in, imitate very well the beauty of Silver Fox; Chinese goat is transmogrified by bleaching into Iceland Fox.

There is, in fact, quite a list of animals whose real names are not found among trade terms of the fur industry: thus the Siberian Mink (*Mustelus siberica*) is always termed Kolinsky; the Polecat (*Mustelus putorius*) is Fitch; the Common Cat is Genet; the Coypu Rat (*Myopotamus coypu*) is Nutria; the Koala (*Phascolarctus cinereus*) is Wombat; the Little Spotted Skunk (*Mephitis interrupta*) is Civet.

**The Procuring of Furs.**—Although fur companies no longer enjoy a monopoly and trapping is free to anyone, subject to legislative restrictions, yet the great majority of furs obtained, in North America at any rate, pass into the hands of several big fur trading companies. There are: The Hudsons Bay Company, Russian Fur Company, Alaska Fur Company, North American Fur Company, Russian Sealskin Company, Harmony Fur Company (Labrador), Royal Greenland Fur Company, American Fur Company, Missouri Fur Company, and the Pacific

Fur Company. To this list may be added such companies as the French firm of Revillon Frères, competitors with the Hudsons Bay Company, who, however, do a wholesale and retail business and offer no skins at public auction.

These companies depend mainly for their supplies upon the work of licensed trappers and native Indians, the great majority of whom are at work in the pathless wilderness of the Mackenzie and Athabasca river areas, and the illimitable stretches of woodland between Labrador and Upper Missouri, visiting twice a day a chain of perhaps thirty traps extending over a circuit of many miles.

The kinds of traps in use vary. In the main, steel jaw traps are used; for marten and for larger animals, dead falls are arranged so that a tug on the bait brings a heavy log crashing down on to the animal's back; small, delicate animals such as the ermine are preferably taken in box traps; rabbits are snared.

There are two ways of removing the skin. There is the "open method," whereby the skin is incised ventrally and taken off much as a man takes off his overcoat. There is the "cased method," in which the skin of the hind legs is slit along the inner line and the skin peeled off from tail to head much as a glove can be peeled from the hand.

Pelts of fox, fisher, marten, ermine, otter, skunk, lynx, and musk-rat are usually cased. Beaver, bear, wolf, and the large furs are removed by the open method.

After removal, the inside of the skin is carefully scraped free from fat and muscle with a blunt bone knife, and is stretched and allowed to dry gradually. Cased skins are stretched, fur inwards, on a wedge-shaped board with rounded edges about half an inch thick, the dorsal side of the skin being wholly on one side of the board, the ventral on another (Fig. 52).

Beaver skins are stretched within an elliptical hoop made of saplings by twine laced to the skin at intervals of two inches. Bear skins are similarly laced in a rectangular frame. Other skins are nailed to a wall or to a pine board by brass tacks, fur side inwards.

Valuable skins are sewn up in muslin and either sent direct to the fur broker or handed in at a fur company's trading post.

**The Marketing of Furs.**—The skins obtained by the trappers converge to certain centres: in Canada to Montreal, Winnipeg, and Edmonton; in the United States to St Paul, St Louis, San Francisco, Chicago, and New York; in Germany to Leipzig

and Frankfurt on Oder ; in Russia to Nijni Novgorod, Moscow, Irbit, and Istum.

From these centres the skins go to the great fur brokers of

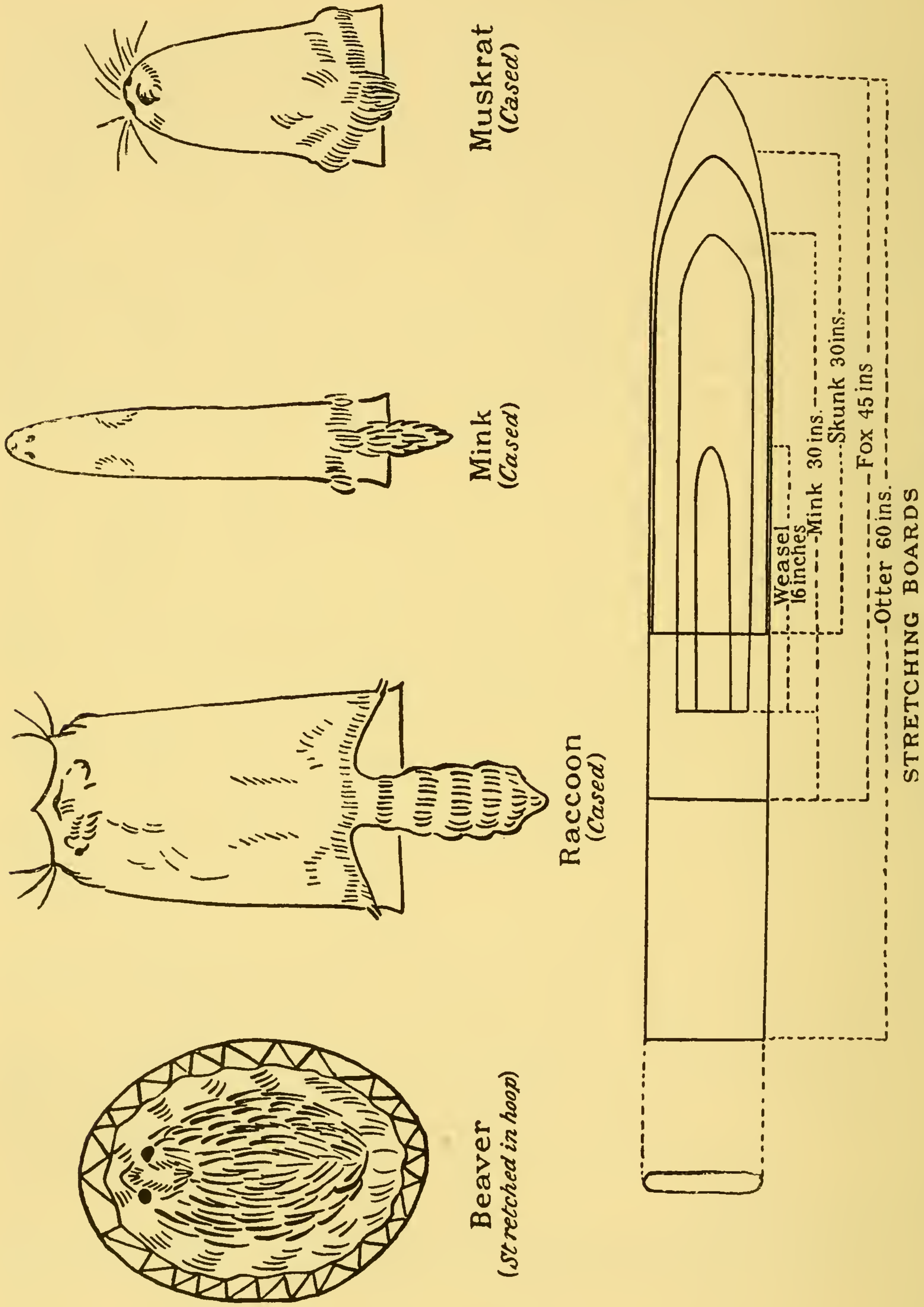



Fig. 52.—The Casing of Pelts. (After Jones.)

London and Leipzig, Montreal and New York, by whom the skins are graded and sold by auction in lots of varying numbers. London is still the largest selling centre of the world, and at the four annual sales—January, March, October, and December

—held by the Hudsons Bay Company, by Messrs C. M. Lampson & Co., and by Frederick Huth & Co., the vast majority of the world's output of furs are dealt with. The war, however, gave a great opportunity to American fur brokers, and very extensive auctions are now held in Montreal, New York, and St Louis.

Grading and sorting is a highly skilled and highly paid occupation, since the methods differ for each kind of fur. As a rule the "original parcel," as it is called, of raw skins is divided into a maximum of five grades of quality irrespective of size and colour. Each grade is then divided into two or three grades of colour. These are divided into large, medium, and small sizes. The skins are then made into lots, first quality lots comprising large, good quality pelts of the correct colour for the particular skin; second quality pelts are slightly inferior in quality, colour, and size; and so on. With some animals, fox for example, the place of origin is taken into account also. A representative sample of twenty-five skins from each lot is taken out to enable the prospective purchasers to judge the quality of the bulk.

**Fur Dressing.**—The final excellence of a manufactured fur depends very largely upon the dresser and dyer. The secret of dyeing seal gave London the monopoly of sealskins. The secret of dressing squirrel similarly gave Leipzig a monopoly of that class of fur.

Speaking generally, with the exception of seal pelts, the raw skins, which reach the dresser in a greasy, fleshy, hard condition are first soaked in or moistened with salt water for twenty-four hours, to soften them and free them from grease. Then they are placed in a "hydro," a machine consisting of a large cylindrical tank containing a revolving perforated basin. The centrifugal action upon the skin in this perforated basin shakes out the superfluous moisture. Then the skins are polished by friction against oak or beech sawdust in a slowly revolving drum, and are then "fleshed," that is to say, the superfluous tissues on the inside of the pelt are shaved off by passage over a sharp knife. Some kinds of pelts can be fleshed by machinery. The pelts have now to be thoroughly aired in rooms heated by steam.

The pelts are still stiff and have now to be made pliable, the operation being termed "leathering." They are again moistened with salt water on the inner side, remaining so overnight. The inside is then thoroughly hand rubbed with seal oil or butter or tallow. The skins are then placed in pairs,

hairy sides together, in a machine which pounds and stretches them until they are thoroughly pliable. This machine has almost everywhere replaced the old method of "foot tubbing," namely, placing the pelts in a huge vat with sawdust and employing semi-nude men to stamp about on them. Some skins—mole, for example—are still foot tubbed, however. The skins are now cleaned by shaking them with dry sawdust, fine as flour, and a little gasolene, in revolving drums for about three hours, then beating them with rattan canes and combing them to eliminate the sawdust.

The dressed skins may now require unhairing and dyeing.

In the case of otter, seal, beaver, and nutria, the coarse outer hairs are plucked out by hand, the skin being first warmed and stretched over a smooth log some eighteen inches in diameter.

Other skins, such as musk-rat, are not plucked but sheared, the coarse outer hairs being cut down to the length of the pelage by a shearing machine.

The following table of comparative durabilities, compiled by Petersen, may be taken as a fair representation of the fur trade opinion. The otter is taken as the standard, other durabilities being represented by a percentage of this :—

| | |
|---|---|
| Otter, natural | 100 |
| Wolverine | 100 |
| Otter, plucked | 95 |
| Bear, black and brown | 94 |
| Beaver, natural | 90 |
| Beaver, plucked | 85 |
| Seal (hair) | 80 |
| Seal (fur) | 80 |
| Seal (hair), dyed | 75 |
| Leopard | 75 |
| Seal (fur), dyed | 70 |
| Mink, natural | 70 |
| Skunk, natural | 70 |
| Marten, baum | 65 |
| Persian lamb | 65 |
| Raccoon, natural | 65 |
| Krimmer | 60 |
| Sable, natural | 60 |
| Wolf, natural | 50 |
| Skunk, tippets | 50 |
| Raccoon, dyed | 50 |
| Marten, baum, blended | 45 |
| Marten, stone | 45 |
| Sable, blended | 45 |
| Musk-rat, natural | 45 |
| Opossum, Australian | 40 |
| Civet, natural | 40 |
| Fox, natural | 40 |
| Opossum, natural | 37 |
| Pony, Russian | 35 |
| Mink, dyed | 35 |
| Marten, stone, dyed | 35 |
| Musk-rat, seal, dyed | 33 |
| Wolf, dyed | 30 |
| Ermine | 25 |
| Fox, dyed black | 25 |
| Kolinsky | 25 |
| Lynx | 25 |
| Squirrel, black | 25 |
| Nutria, plucked | 25 |
| Fox, blue | 20 |
| Marmot, dyed | 20 |
| Mink, Japan | 20 |
| Squirrel, black blended | 20 |
| Opossum, dyed | 20 |
| Chinchilla | 15 |
| Goat | 15 |
| Astrakhan-moire | 10 |
| Mole | 10 |
| Hare | 10 |
| Rabbit | 10 |

The dyeing of furs is a very delicate and closely guarded secret of the firms that carry out the work. Speaking very

generally, there are several methods in use. Pelts of rabbit and musk-rat may be dipped in huge revolving tanks of dyestuffs until the skins are soaked. More expensive pelts are "topped," that is to say, the skin is brushed with the dye so that only the outer portion of the hair is coloured. A final lustre is often produced by hand brushing with an application of sulphuric acid.

Dyeing and plucking, of course, affect the durability of the fur. Unless the dyeing is extremely well done, even when the pelt is dyed by hand brushing, the dye will in time soak through the pelage to the skin and weaken it.

In conclusion, it may be added that the statistics of any of the fur auction sales are sufficiently imposing to create a feeling of alarm and doubt not only in lovers of wild life but also in fur traders themselves as to the conditions of the future. Such animals as the sable, marten, chinchilla, beaver, and otter are undoubtedly declining rapidly in numbers, and the sea otter is, commercially, extinct. Even such prolific animals as musk-rats and squirrels are being taken in such large numbers that their relegation to the status of rare animals is only a matter of time. The chief areas from which furs are taken, notably Alaska, Northern Canada, and Siberia, are certainly so vast in extent, so wild and impenetrable, and so sparsely populated, that the extinction of any animal to the extent to which the bison was wiped out in the past is hardly likely to occur. Labrador alone is 530,000 square miles in extent, twice the area of Germany, and has a population of 17,000 at the outside. Marten and mink, fox and musk-rat will always occur somewhere or other. It should not be difficult, therefore, to devise conservation measures which, without hampering what is after all a legitimate and useful industry, will enable animals to maintain a constant normal level of abundance.

It must be remembered that other causes besides the activity of man may bring about considerable fluctuation in the number of fur bearers in any one year. Such animals may, according to the observations of Macfarlane and of Seton, be divided in this respect into three groups, namely :—

(*a*) The herbivorous rodents, mice, rabbits, ground squirrels, musk-rats, and the like, which are very prolific and increase in numbers until they reach a high degree of abundance. Then they either constitute a mouse plague, as described in Chapter XX., or they are suddenly reduced to a minimum by an epidemic of some disease. That is to say, they show periodical abundance and scarcity.

(*b*) The various predatory animals which depend upon these small animals for food, and so fluctuate in numbers in any particular in correlation with the fluctuations of small rodents. This category includes the Mustelid animals such as fisher, marten, mink ; the lynx, which is largely a rabbit feeder ; the foxes ; and to a lesser extent the skunk. The large predators such as wolves and coyotes are not so dependent upon the abundance of small game in any one area, since they can travel far afield.

(*c*) Animals which feed on a mixed or exclusive diet of insects, fruits, and fish, and do not show periodical fluctuations. This category includes the black and brown bears, the raccoon, otter, and beaver.

This question requires further and more extensive study, since a knowledge of the basic causes of such fluctuations may provide a method of predicting to a large extent the years of abundance of the larger fur-bearing animals, and so may influence very largely the framing of legislative measures designed to conserve these animals.

## CHAPTER XXXIII

## FUR FARMING

There can be little doubt that the one hope of preserving the more valuable and the larger fur-bearing animals lies in the possibility of domesticating them, or at any rate of rearing them in captivity. There may be said to be two kinds of such fur farming, namely :—

(*a*) The production of a new variety of some animal already domesticated and easily reared, such as the goat, sheep, rabbit, cat, or dog, with a coat of such quality as to have a value as fur.

(*b*) The rearing in captivity of some wild animal whose fur has already an accepted market value; such an animal as the beaver, mink, otter, skunk, fisher, or fox.

The first type of fur farming has been carried out for centuries. Goats have always had a fur value. Dogs and cats and rabbits to-day have also a fur value.

Perhaps the most important example of a domesticated fur-bearing animal is that of the so-called **Karakul sheep.**

The Karakul sheep is a Central Asiatic breed, the centre of its distribution being Bokhara, in Turkestan. It derives its name from Kara-kul, meaning the black lake, a village in Bokhara.

The Karakul sheep has a fleece which is shaggy and coarse, and sells commonly as carpet wool. The newly-born lamb, however, has, when less than five days old, a pelt which is glossy black, curly, and of high lustre. Such lambskins are exported at the rate of 40,000-50,000 a year through Persian and Russian marketing centres to Europe and North America and sold there as Persian lamb, or broadtail or baby lamb. A similar but inferior kind comes from Northern Persia and constitutes Shiraz. A variety from Russia with longer hair, more open curl, and less lustre sells as Astrakhan. From the Crimea comes a grey kind, sold as Krimmer.

A good skin should be taken from a lamb less than five days old, since after that age the curl coarsens and the skin will fetch the price of a common fur only, whilst after six weeks

old the pelt is not fur at all but wool. Slinks or still-born lambs provide the most valuable pelts of all.

The average quality of skins from European Russia, Asia Minor, Trans-Caucasia, and Western Turkestan is declining rapidly, a larger and larger proportion each year being of the open curl or Astrakhan quality, a consequence probably of the crossing of Karakul sheep with mutton or wool sheep such as the Afghan fine wools, the Achuri and Chulmi fat rumps, and so on.

Karakul sheep breeding, however, is now established in North America through the efforts of Dr C. C. Young of Texas, who managed to import fifteen Afghan Karakul sheep to Texas in 1908. After great difficulties some Bokhara rams were obtained in 1912, and in 1914, in the teeth of Russian quarantine opposition, a herd of twenty-one rams and ewes from Bokhara was shipped from Libau to Baltimore.

The initial experiments in establishing the sheep were made in Texas, but later were transferred to Prince Edward Island. A herd has also been maintained on the British Government Farm in Inverness-shire, Scotland, and one at the United States Government Farm at Beltsville, Maryland.

Several years' experience has shown that Karakul sheep are usually hardier than European breeds and can flourish where other sheep would starve. Close inbreeding, however, whilst apparently not physically detrimental to the sheep, makes the wool finer and induces a more open curl in the lambskin, an undesirable quality. Future progress of the industry will depend probably upon successful hybridisation of Karakuls with native ewes of a coarse class such as Highland Blackface, Lincoln, Cotswold, Mexican Hairy, Persian Fat-rump, or similar breeds.

**Rabbits.**—Rabbit breeding for natural fur, that is to say for skins which do not require to be dyed or doctored, is a special industry in which the value of the flesh of the animal is less than that of the skin. It must be noted, therefore, that the skins of rabbits killed at four and a half to five months old, or less, for table purposes are of little value as fur, whatever their size or colour, and are in demand only by felters and hatters.

Skins which are to command high prices as furs should be obtained from animals not less than six to nine months old, not less than 7 lbs. in weight, killed in the middle of winter.

The principal breeds of rabbits with skins of fur value are Chinchillas, Champagne Silvers, Havanas, Blue Beverens, Himalayans, and short-coated, self-coloured black, yellow, and

white rabbits of various breeds, notably Belgian Hares, English, Dutch, and Polish.

In all cases skins should be as nearly self-coloured as possible, at any rate between shoulders and tail. Animals with spots or other marks on the back are of little interset to the fur producer.

The **Chinchilla** is a large, light-coloured animal whose coat, owing to a mixture of black and white hairs, is of a silvery-grey colour similar to that of the expensive South American chinchilla which it is intended to imitate. The standard type of coloration laid down by the British Chinchilla Club is as follows : That part of the hair next to the skin to be slate-blue, immediately followed by pearl-grey ; working towards the surface it merges into white, whilst just at the end of the hair it becomes black ; scattered over the body are hairs which exceed the length of the main coat and are entirely black. An exquisitely soft texture and density of coat are essential, and the coat is to be no less than one inch in length.

The Chinchilla rabbit is believed to have originated in France through hybridisation between black and tan, self blue, and the ordinary wild rabbits. Very young animals, as a matter of fact, are sometimes coloured somewhat like wild rabbits.

A variety of Chinchilla produced recently is the *American Chinchilla*, a product of hybridisation of Standard Chinchilla bucks with does of the Flemish Giant, a popular general utility breed. By selection of heavyweight Standard Chinchillas there has been produced also the *Heavyweight Chinchilla* in the United States.

Somewhat similar to the Chinchilla in coloration is the **Champagne Silver** rabbit. The colour, however, resembles more that of platinum or dull silver than the warmer grey of Chinchilla. The under fur is blue in colour.

The **Havana** breed is a self-coloured brown or chocolate variety which originated as a sport in Holland among some rabbits running loose in a stable. The winter coat is very thick and close, and its colour makes it a good imitation of the skin of the marten or the beaver.

The **Blue Beveren** or Vienna variety comprises two types of animal, namely :—

(*a*) The *Brabançon*, a small animal with brown eyes and short coat of a medium or dark blue colour, and of low fur value.

(*b*) The *Giant Beveren*, created by an Austrian fancier by hybridising Flemish Giants, blue Lorraine Giants, and the

French Lop; it is a large animal with steely blue eyes, long silky lustrous coat of a lavender-blue colour, and a dense undercoat; the coat is twice as long as that of the ordinary rabbit.

There is a white variety of Beveren, arising probably from a cross between the Blue Beveren and the White Angora.

The **Himalayan** variety is thought to have originated in Northern China. It is white with nose, ears, feet, and tail black. The fur is of silky texture and makes a good imitation of ermine.

Other breeds of lesser fur value, however, are **Black and Tans** or Blue and Tans, a breed of small rabbits whose coat colour is brilliant black or clear dark blue with tan markings; **New Zealand Reds**, a self-fawn variety; **Blue Imperials,** a Maltese blue coloured breed created by the English rabbit fancier, Miss Illingsworth, by the hybridisation of the Lop, Angora, and Dutch breeds; **American Blues,** a large slate-blue type, probably a mixture of Blue Beveren, Imperial, and Flemish Giant; **Polish**, a small white, short-coated rabbit; **English,** a white animal with spots and markings either of black, blue, grey, or tortoise; **Dutch,** a two colour rabbit, white on the chest, front, throat, legs, forebody, and lower part of the head, but black, blue, grey, or tortoise on ears, cheeks, and hind body; **Flemish Giant,** a large, massive animal of various types of coat colour, steel grey, black, white, blue, and so on; **Belgian hares,** the racehorse of the rabbit class as regards activity and sprightliness, and a rich red coloured animal.

The **Angora** breed of rabbit, although not, strictly speaking, a fur variety, may be mentioned here. It is an animal with a coat four to five inches long on the back and sides, and of remarkable density; the colour may be white, blue, fawn, black, or smoky, but whatever colour the rabbit possesses, should be uniform; the coat is very soft and silky, and can be plucked off periodically without injuring the animal. This so-called rabbit wool is in great demand and will fetch from thirty to forty shillings or eight to ten dollars a pound, and an adult animal will yield 9-10 oz. yearly.

Rabbits intended for fur production should be reared preferably in roomy pens in batches of ten individuals of the same sex. A batch of males will live amicably together if they have been castrated when three months old. To obtain skins of good colour and thickness, plenty of shade, cold conditions, and plentiful food are required.

The domestication or semi-domestication of wild fur-bearing

animals is a comparatively recent venture, certainly, as regards large scale domestication, not more than fifteen years old.

A distinction ought to be made between the term **fur farming**, which implies the rearing of wild fur bearers in confinement, subject to artificial feeding and to a more or less amount of human handling, and the term **fur ranching**, which implies the protection from enemies of some fur-bearing species within a limited tract of country such as an island, forest, or marsh, and not characterised necessarily by artificial feeding nor by human handling.

Obviously, true fur farming is not an economic proposition unless the selected animal can be reared on a large scale without any loss of condition due to confinement, and unless the individual skins command a high market price.

Fur ranching, on the other hand, can be carried out with animals such as musk-rats, whose individual fur value is low, but whose aggregate fur value is high, owing to their prolific breeding habits and the ease with which they can be captured.

True fur farming to-day concerns itself, therefore, chiefly with the silver fox, mink, skunk, raccoon, marten, fisher, and beaver in order of importance. Fur ranching concerns chiefly the musk-rat, and to a lesser extent the blue fox.

**Fox Farming.**—The original home of silver fox farming is Prince Edward Island in Canada, and there the business was started by optimistic individuals who dug their foundation stock from dens in the woods. For a long time they experimented in secret, but their rapidly increasing revenues betrayed them, and in 1910 a great boom in fox farming occurred. The scramble to procure foundation stock sent prices up, and silver foxes per breeding pair rose from 3,000 dollars in 1910 to 20,000 dollars in 1913, and as much as 35,000 dollars was paid for a breeding pair. Company after company was floated. Dalton, one of the pioneers, obtained 34,175 dollars in London for twenty-five pelts.

The European War disorganised markets, but gradually the new industry became stabilised, and the days of wild speculation in breeding stock are over.

At the time of writing, 1927, quality breeding stock can be obtained at prices ranging around 2,000 dollars the pair, and good pelts bring from 200-1,000 dollars each. A fox farm can thus yield good returns for money invested, since a breeding pair should produce each year a litter of four pups, and these pups can be killed and pelted when ten months old.

There are to-day about 2,500 fur farmers in the United States

and Alaska, and about 1,500 in Canada, the majority raising foxes. Fur farming is also being undertaken in European countries and in Japan. In Great Britain, up to the end of 1926, there were about ten fox farms, comprising some 500 animals.

The term *Silver Fox*, as used by furriers, refers to certain melanic varieties of the American Red Fox, an animal normally of a rich red or dull yellow colour, but having usually a mixture of brown or grey hairs, black markings on feet and ears, a white tipped tail, and certain groups of white hairs on rump and back.

In the so-called **Cross Fox** variety, black hairs predominate on the feet, under surface, and legs, and the red hairs occur chiefly on shoulders and back so as to give the appearance of a red cross on a dark ground.

In the typical **Silver Fox** variety there is still more of the black coloration, and the reddish hairs are replaced by silver ones so that the animal is black with an admixture of silver tipped hairs. Silver foxes vary from animals entirely silver to animals entirely black, save for a few white groups of hairs on rump and back.

In the **Black Fox** variety the white hairs are totally absent, except at the tip of the tail.

Speaking generally, the Black Fox is exceedingly rare and consequently more valuable, the Silver Fox is scarce, and the Cross Fox is fairly common.

The most valuable variety of Silver and Black Fox is without doubt the Prince Edward Island variety, representing melanic varieties of the geographical sub-species of Red Fox, *Canis vulpes rubicosa*; but Silver Foxes from the Athabasca river, the Yukon, and Alaska are often of great value. These regions should provide ideal conditions for fox farming if venison and fish are procurable readily and cheaply. It may be noted, however, that silver foxes are being farmed successfully in practically all of the Northern States of U.S.A., ranging from New England westwards to Washington and Oregon, and also in the cooler portions of California, Kansas, Colorado, Iowa, Ohio, Missouri, Illinois, Pennsylvania, New Jersey, and Massachusetts.

A fox farm should be located preferably on a knoll or on a level, well-drained piece of land sloping gently to the south, and situated in a district where the climate throughout the year is cool, damp, with snow and frost in winter. There should be sufficient trees to provide summer shade and to provide seclusion. The soil should preferably have a hard pan sub-soil in order to

prevent the animals from burrowing. Each pair of foxes is kept in a pen of heavy galvanised wire netting of one and a half or

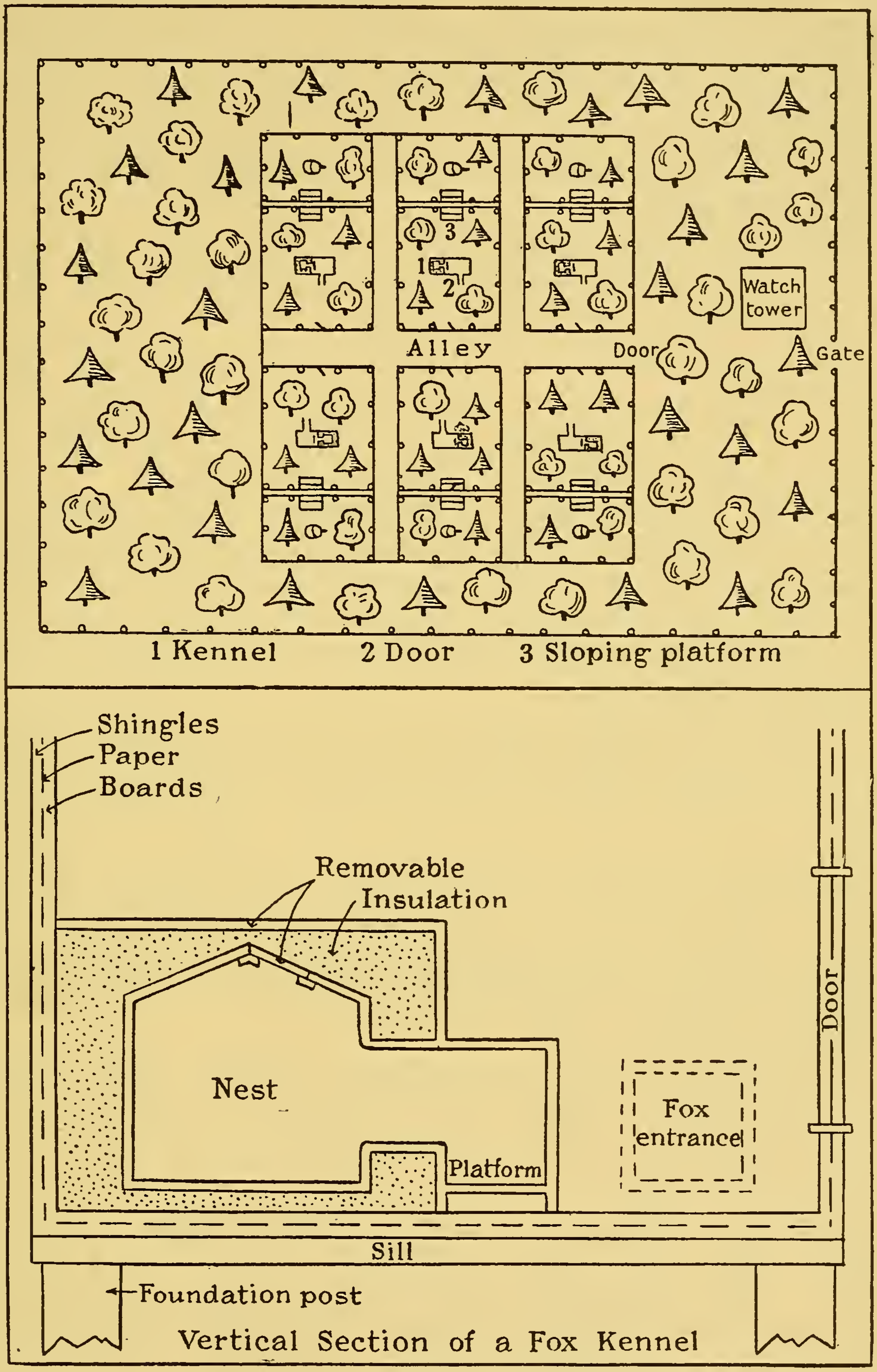



FIG. 53.—A Type of Fox Farm. (After Jones.)

two-inch mesh and sixteen gauge, sunk three feet into the ground so as to foil burrowing; the pens may be oblong, square, octagonal, or circular, but should cover each between 600 and

750 sq. ft., large enough for the animal to run about in at full speed ; the height of the pen should be eight to ten feet in order to prevent the animal from leaping out, but if the pen be covered, six feet of height is sufficient. Some farmers prefer a movable pen so that the site can be changed occasionally.

Part of the pen should have good hiding cover, as the fox is extremely nervous and timid ; female foxes in particular are liable to fly into hysterics at the approach of human beings and kill their young.

There should be well-drained and sunny areas of the pen for the pups to play around, and the ground surface should be turfy or covered with pine needles.

Inside each pen there is a kennel or den, preferably double walled. This is a wooden affair entered by a sloping tunnel termed the *chute.* There are two types of kennel. The overground or movable kennel is being widely adopted for ranch purposes as it is drier, better ventilated, and easily cleaned and moved. On the other hand, the underground kennel is warmer and more sound proof. Within the kennel itself there should be a nesting box or bed for the female when suckling her pups ; such a bed should be about eighteen by twenty inches in area, by twenty inches high.

A space of two feet is left between pens usually, and the layout of the pens varies ; they may be in rows or in circles, the whole layout being surrounded by a high fence of wire netting.

A necessary structure in a fox farm is the lookout or watch tower, a conical structure in the centre of the farm from whose summit a general observation can be kept over the pens, thus obviating any risk of frightening whelping or sucking females by going too near the pens.

The diet may consist of horse flesh, butchers' scraps, rabbits, birds, fish, and so forth, but an excessive meat diet causes intestinal troubles, and the menu should therefore include eggs, fruit, and wild berries.

The fox is liable to infection by several kinds of internal parasitic worm, and much mortality among pups is caused thereby. Three parasites commonly met with are the roundworm *Belascaris marginata*, the hookworm *Ancylostoma caninum*, and a lungworm *Eucolius œrophilus.* Much suffering may be caused also by the ear mite *Otiodectes.*

The animals are handled when necessary by gripping them by the neck in a pair of large tongues, the tongues being held in one hand, the tail and hind legs of the fox in the other hand.

Killing is carried out either by crushing the thorax, or by injecting a quantity of 3 per cent. strychnine sulphate into the thorax.

**Mink Farming.**—Mink farming is somewhat in the experi-

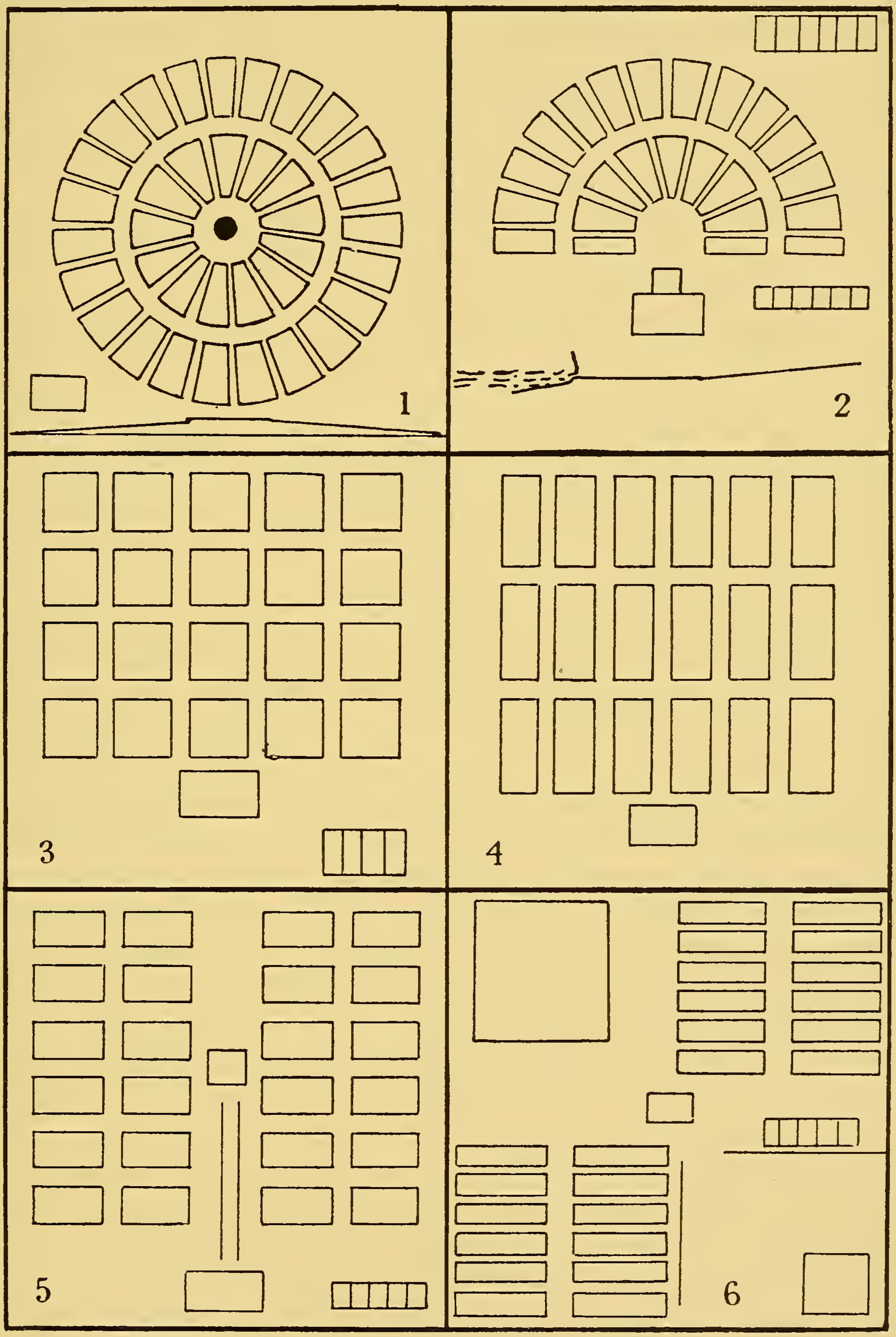



FIG. 54.—Types of Fox Farm Formations. (After Tufford.)

1, Circular. 2, Semi-circular. 3, 4, Square Types.
5, Split Units. 6, Separate Units.

mental stage, and the low price of mink skins as compared with those of foxes has tended to discourage the industry.

A mink farm should be situated ideally in a secluded woodland area on the banks of a stream or lake. Usually a separate pen is required for each animal. Such a pen should be about eighteen feet long by four feet wide; one-third should be covered in, one-third should be open, and the remaining third should be an enclosed portion of the stream.

On the other hand, many mink farms utilise merely wooden pens about five or six feet square.

Another system is to rear a litter, taken from the mother when six or seven weeks old, in a communal pen with a runway to an enclosed piece of water.

The usual food is bread and milk, meat, fish, and dog biscuit. Some breeders use sparrows and rabbits as food. The animals are fed twice a day.

The chief difficulty in mink farming is that of securing foundation stock. The wild adult is almost untamable, and is said to commit suicide when held captive. Young animals, however, become very tame and are easily handled; when mature they breed readily in captivity.

**Otter Farming.**—The otter thrives in close confinement and becomes very tame. It can be easily reared in simple wire mesh pens, enclosing a portion of a stream. The favourite food is fish and crustacea, so that in siting an otter farm due consideration should be given to the possibility of procuring such food in abundance. Under ordinary conditions, however, otters do not breed readily in captivity, but possibly this could be overcome by providing sufficiently normal conditions.

**Skunk Farming.**—Skunks can be kept in captivity under conditions similar to those described for mink farming, but as the animals are less pugnacious, a number may be allowed to run together. They require, however, a considerable area in which to roam about, and should have well-insulated or artificially heated dens, each about a cubic foot in dimension. A piece of woodland, enclosed by a sunken wire fence about three feet high and provided with plenty of artificial dens, would be an ideal situation. There should be at least an acre of ground for each fifty animals. The young skunks can be deodorised when about two months old by removal of the anal scent glands. The methods used are described in detail by Holbrook. An expert can disarm seventy to one hundred in a day and not lose a single one.

**Fur Ranching.**—In the case of otters, skunks, minks, beaver,

fur ranching is preferable to fur farming when possible. An extensive range of country is enclosed and a certain amount of artificial feeding and housing is provided when necessary. The animals, however, are not handled but are caught, when required, by trapping.

Ranching on these lines was carried out to a certain extent in Russia before 1914 with the Sable. To-day it is a method of fur production confined to two animals, namely the Blue Fox and the Musk-rat.

For several years Blue Foxes have been successfully preserved in this way on several islands off the coast of Alaska, leased from the United States Government.

It may be added, however, that the idea formerly prevalent that the Blue Fox could not be reared successfully in confinement has been shown to be erroneous, and every year an increasing number of Blue Foxes are being reared successfully under conditions similar to those adopted in Silver Fox rearing.

Musk-rats are particularly suitable for rearing under ranch conditions, since they inhabit marshy country unsuitable for agriculture and thus cheaply to be rented; further, they require no artificial feeding and are enormously prolific, having from two to five litters of twelve to twenty young each year.

They can be reared successfully in pens in close confinement, but the ideal situation for musk-rat raising is a marsh where there is no running water.

In such a place a large number may be kept in a small area without fencing, if a sufficiency of natural food such as wild rice, pond lilies, arums, sedge, and other water plants be present. If the site be a small lake or marshy basin with water flowing in and out, a fence will be necessary; and such a fence requires a considerable outlay, since it must consist of fifteen-gauge wire of one and a quarter inch mesh, and must be sunk a foot into the ground, or even deeper when crossing a stream. In some localities a fence sunk three feet into the ground, and in height eight feet above ground, is used in order to exclude coyotes and minks.

The latter enemies may be prevented from climbing over the fence by the provision of a strip of galvanised iron, one foot deep, along the upper edge of the mesh fence. A suitable marsh should be under four to five feet of water all through the year.

Such musk-rat ranches are operated extensively in Canada. In New Jersey and Maryland, Delaware and Pennsylvania, where the best black rats are to be found, the musk-rat marshes are leased by the owners to trappers, and trappers and owners

unite to protect the marshes from poachers. Usually the owner receives half the fur caught, the trapper getting the other half and the meat, which is sold as marsh hare.

Trapping operations are carried out during the first three months of the year.

Some of these musk-rat marshes are worth more than cultivated farms of similar acreage in the same neighbourhood.

## CHAPTER XXXIV

# ANIMAL CONSERVATION

THE basic foundation of any discussion of the wide problem of animal conservation should be a clear acceptance of the fact that the indiscriminate encouragement or protection of an animal may prove to be a policy equally as mischievous as any policy of indiscriminate destruction.

The relation between associated forms of animal life is a very close one, and the natural balance may easily be upset. The following example is given by Fisher : An extensive marsh in northern New York State was frequented by numbers of ducks, rails, snapping turtles, frogs, and other aquatic forms. The turtles' eggs, deposited in the sandy beach around a lake, attracted large numbers of skunks whose depredations allowed only a small percentage of eggs and young turtles to survive. When skunk fur became fashionable and valuable the skunks were almost exterminated. The snapping turtles multiplied greatly, and intense competition for food forced them to add ducklings to their fare, until in turn the ducks and other aquatic birds went down considerably in numbers. The great aggregation of turtles attracted the attention of agents of the food markets and restaurant keepers, and turtles were henceforth caught in large numbers and shipped away in barrels. Skunk fur also dropped somewhat in market price. The final result was that the surviving skunks gathered on the old beach and devoured the eggs of the surviving turtles, the birds now remained unmolested, and the marsh reverted to its original populous condition.

A similar but better known example of the danger of disturbing the indigenous animal association of a locality is the case of the introduction of the mongoose into Jamaica to cope with the plague of rats.

The mongooses dealt with the imported rats and the native cane rats effectively, then turned their attention to ground birds, lizards, and poultry. As these insect-eating agents became reduced in numbers, insects and ticks multiplied exceedingly and plants and domesticated animals began to be affected.

Speaking very generally, from the point of view of animal conservation, wild animals may be grouped in three categories, namely :—

(1) Animals which should be *exterminated* or rigidly reduced in numbers owing to their proved danger to man or to domesticated animals, or to useful animals, or to food crops; this category includes a very large number of protozoa, helminthes, and arthropods ; it includes a large number of graminivorous and omnivorous birds, notably the English sparrow, and certain carnivorous birds such, for example, as the New Zealand kea parrot and certain hawks and owls ; it includes a very large number of poisonous snakes, of carnivorous mammals, of graminivorous and herbivorous mammals, notably rats, voles, and rabbits.

The repression of this category has already been discussed in previous chapters.

(2) Animals which should be *partially* protected ; this category includes, firstly, animals which form the basis of such industries as whale and seal fisheries, shellfish and food fish industries, fur trading ; secondly, it comprises the fauna of areas where native populations support themselves by hunting or fishing ; thirdly, it comprises many birds and mammals whose food activities are on the whole a benefit to man during certain seasons of the year, but which at other times of the year, or if in excessive numbers, may be distinctly injurious to crops or livestock. Such is the case, for example, with rooks, crows, pheasants, and many other birds of omnivorous habits.

(3) Animals which should be *completely protected* and, if possible, actively encouraged ; this category comprises such wild animals as possess the potentialities of domestication, animals of food or fur value which are on the verge of extinction, insect-eating and snake-eating animals, and animals which possess particular scientific interest and value.

The complete extinction of any animal would seem almost impossible.

It probably *is* impossible if the animal has unrestricted food habits, has a wide range of distribution, is adaptable to a variety of environmental conditions, and is a prolific breeder. The difficulty of even checking the multiplication of such animals has been already discussed in the case of insect pests and of such animals as the rat and the rabbit.

On the other hand, where an animal has restricted or peculiar food habits, is restricted in distribution, is a slow breeder and,

above all, if it possesses commercial value, then extinction is certainly possible through human agency.

There are numerous examples of animals, formerly of great abundance, which have been completely exterminated or have only been rescued from extermination by conservation measures.

The **Great Auk,** a diving bird about the size of a goose, was formerly abundant in certain islands on the North Atlantic but was killed in thousands for the sake of the oil it contained, and is now absolutely extinct. The **Dodo**, a most interesting gigantic ground pigeon of Mauritius and Rodriguez, was exterminated very soon after the discovery of these islands by the Dutch, owing to the depredations of vessels' crews and particularly through the killing of nestlings by the rats, which were introduced into the islands from European ships. The **Passenger Pigeon,** whose flocks of millions of individuals darkened the skies of Canada and the north-eastern United States less than a hundred years ago, has been completely sacrificed to the market and the pot. Not much longer than fifty years ago, one town alone in Michigan marketed three carloads of pigeons daily for forty days, a total of nearly twelve million birds. Another town in Michigan marketed sixteen million pigeons in two years. To-day not a single individual survives.

The South African **Quagga,** an equine animal that might have proved amenable to domestication, was exterminated by Dutch farmers early in the nineteenth century because its hide was useful for whips.

The **American Bison** formerly blackened the plains between the Rocky Mountains and the Mississippi River; so late as 1871 their numbers, in spite of many years of continuous persecution, were estimated at five millions. The construction of the Union Pacific Railway cut the bison into northern and southern herds, and provided marketing facilities for bison skins. Between 1871 and 1875 the southern herd was wiped out of existence. By 1883 the northern herd had almost disappeared; in 1889 only 645 animals were estimated to exist in the United States, and to-day the only wild bison are certain small herds of so-called "wood bison" in the area north of the Peace River in Canada. Only the conservation measures of the Canadian and United States Governments have saved the bison from complete extinction.

Of the European bison or "wisent," a few still survive in the forests of East Prussia and of North-western Caucasus.

In 1741 the Russian explorer Behring was wrecked on Behring Island, one of the Aleutian Islands of the Northern

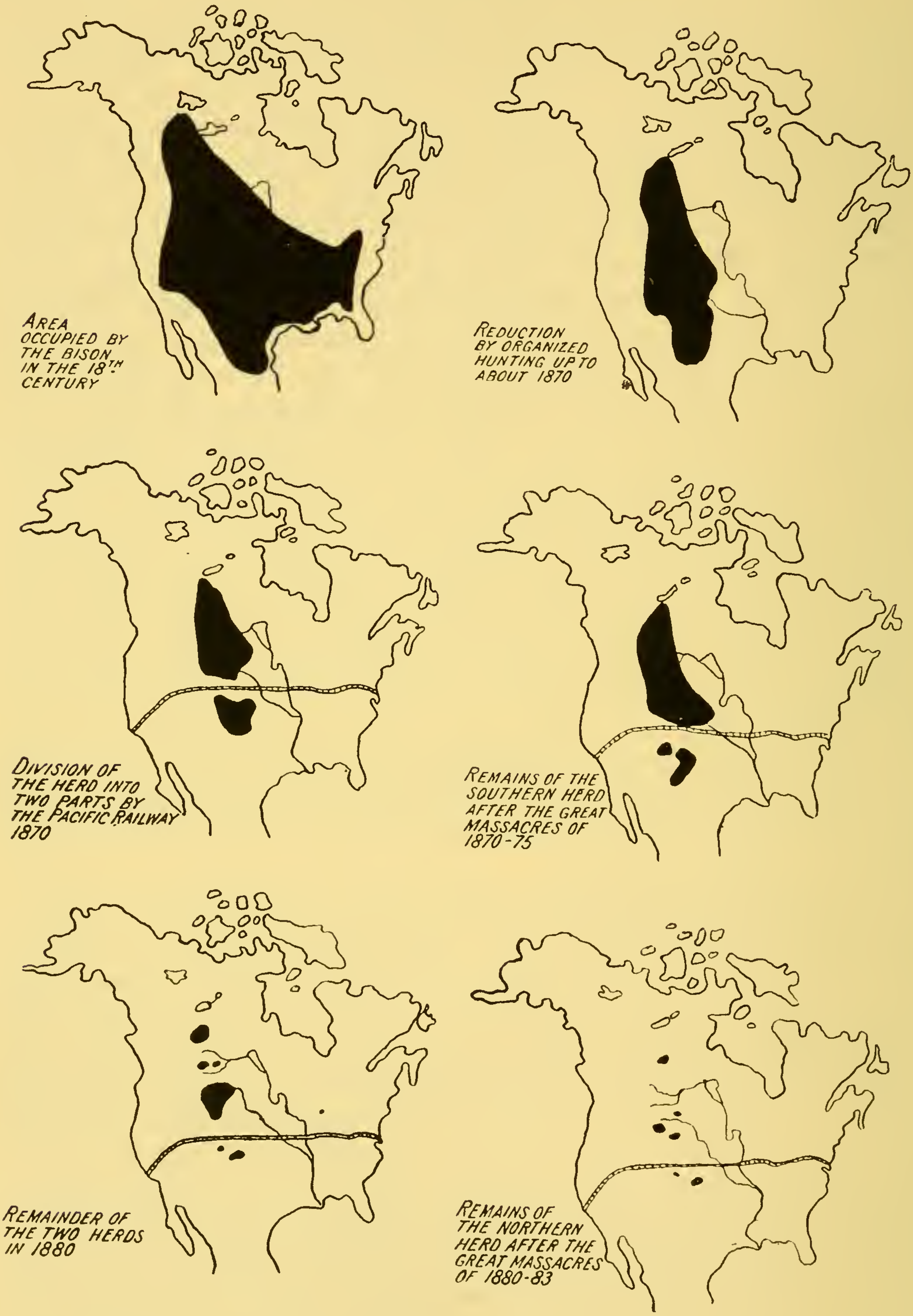



Fig. 55.—The Extermination of the Bison in North America. (After Hornaday.)

Pacific, off the mainland of Alaska, and for a year he and his crew supported themselves on the flesh of a large animal

about six feet long—later known as the **Sea Otter**—which swarmed over the seaweed beds there, and they used its skin, the most beautiful and valuable in the world, for clothing their nakedness and for stopping up the chinks of their underground dens. When they rafted back to Asia they brought back news of this animal and 1,000 skins, which Chinese merchants eagerly bought for 30-40 Chinese dollars apiece. The news was like that of the discovery of a gold field. Four years after Behring's return there were seventy-seven different private Russian companies hunting sea otter with the help of a riff-raff of Siberian convicts and cossacks.

Oonalaska and Kadiak were two main headquarters. Hundreds of Alaskan natives were brutally coerced into service. Fifty years later there were at least sixty different fur companies engaged under many different flags. The takings were enormous. Skins worth thousands of pounds could be obtained from the Nootka tribes for a few shillingsworth of old iron.

One ship, a year after Behring's return, sold its cargo of skins for £100,000 ($500,000). The bulk of the trade became eventually controlled by one huge company, the Russia-American Fur Company, whose representative ruled at Sitka like a little Czar. Gradually the animal became scarce. Islands which at the end of the eighteenth century had yielded their thousands of skins each year, by 1830 were yielding in hundreds, and when Russia sold Alaska to the United States, the otter fishery was finished and the area in Russian eyes was worthless.

A few animals still exist in the Aleutian and Commander Islands, and in a few localities along the American and Japanese coasts, and as the sea otter was included in the Fur Seal Convention of 1911, there is a possibility that it may re-establish itself.

The foregoing examples will illustrate the ease with which an animal can be exterminated. The list could be considerably extended.

The gradual destruction of animal and plant life is to a certain extent unavoidable. The steady progress of agriculture brings under human control areas formerly devoted solely to wild life. The balance of nature is to a large extent destroyed. The breeding haunts and food supplies of such animals as are dependent upon forest or marsh or prairie dwindle in extent, and the interesting tenants of the former wilderness die out or are driven away. Much as we may deplore the passing of the bison, his former range extended over an area destined to be the most valuable wheat-growing region of North America.

When these vast areas were brought under cultivation, his existence was bound to become menaced. Railways and the settlements along them were bound to restrict his migrations, and the end of the bison as a wild animal was only a question of time.

Unavoidable also is the spread of industrial areas and the consequent destruction of vegetation and pollution of rivers and streams.

Avoidable, however, should be the depredations of the market hunter, the fur and feather trader, the hunter of wild fowl and birds' eggs, the bird trapper. Avoidable also should be the ravages of the "fool with the gun," the sportsman, gamekeeper, field naturalist, and ornithologist, the last two being often mere exterminators of rare birds or rare insects.

The methods by which the extermination of an animal can be prevented fall into two groups, namely, **passive encouragement measures** and **active encouragement measures.** Passive encouragement can be effected by legislation if such legislation can be vigorously enforced. Active encouragement can be afforded by the provision of sanctuaries, varying in size between a huge tract of wild country, down to a few bird boxes in a city park.

Legislation may be international, national, or local. In each case laws are passed to prohibit the taking of animals, or of young stages of animals, during either a certain period of the year, termed a "close season," or during a period of several years, or in a particular tract of country.

An example of international legislation is afforded by the Fur Seal Convention discussed in Chapter XXX.

Another example of international agreement in the enactment of legislation concerning animal conservation is afforded by the international treaty signed in 1916 between Canada and the United States for the federal protection of all the migratory birds of North America north of Mexico.

National legislation may be exemplified by the Wild Bird Protection Acts of Great Britain, a series of enactments to protect birds and eggs between 1st March and 1st August in every year; by the legislation that many countries have enacted, or are intending to enact, against the discharge of refuse oil from oil-burning steamers in coastal waters; by the various Game Acts and Game Ordinances of Canada, North America, and the regions of Africa under British influence.

Such Game Acts are very difficult, of course, to frame in regions where there is an indigenous population dependent upon the catching of animals for food or for skins. The usual practice is to restrict the methods of native hunters—to prohibit, for

example, the use of poison or of grass burning—and to restrict the activities of the sportsman by expensive and limited licences. The activities of the ivory and plumage trade can be curtailed considerably by limiting the local centres at which such trophies can be marketed, and by exercising a close surveillance over the nature of the ivory or plumage or game trophies brought in for sale or for export.

The African elephant offers an interesting example of the value of even partial protection of an animal.

Since 1900, elephant hunting in almost every elephant area of Africa under European influence has been regulated by the issue of licences, and by the prohibition of the slaughter of females or of males with tusks of less than 30 lbs. weight the pair. Of course a considerable number of animals are killed by poachers and by native hunters in remote districts, and a fairly large illicit trade in small ivory and female ivory from British territory goes on through Abyssinia. In spite of this, however, protection has been successful in arresting the rapid decline in numbers of elephants which would otherwise have occurred, and although large tuskers are certainly becoming more uncommon, there has probably been little numerical decrease of the animals as a whole during the last thirty years.

As a result of the large herds becoming broken up, small troops and harried individuals have taken to attacking cultivated crops in some districts of Africa, and protection, in consequence, has had here and there to be suspended. Thus in 1908 the Government of Rhodesia suspended protection in the Lagamundi district owing to the reported destruction of native crops, but unfortunately allowed a very large number of animals to be slaughtered by commercial hunters, whereas the destruction of the leaders would probably have frightened the elephant troops away. Similar withdrawal of protection has also been necessary at times in districts of Kenya and Uganda. In the latter area, for example, it has actually been necessary to devise control measures.

Measures suggested for Uganda by Swynnerton comprise the provision of recognised sanctuaries sufficiently provided with food to encourage elephants to remain within them; encouragement of the native population in sparsely populated areas to concentrate in well-settled districts; the defence of selected cultivated areas by salaried European or Sikh shooters with a few well-supervised native assistants and a few spare guns for scaring purposes; and the gradual herding back of elephants into the sanctuaries by organised agricultural development of districts.

An example of the difficulty of protecting an animal which

ranges over a wide area is that of the caribou, or wild reindeer, of which several species occur in the extreme north of Canada and in Alaska.

The barren ground caribou (*Rangifer arcticus*) offers a close parallel to the bison in its economic status and habits, except that whereas the bison as a wild animal is extinct, the caribou is one of the most abundant large mammals of the world. It compares with the bison in its extraordinary biennial migrations of hundreds of miles, and in its importance as a provider of meat and clothing for whole tribes of people who are mainly dependent upon it.

During the summer time the caribou keep to the seacoast and tundras of Northern Canada between Hudson Bay and Alaska, feeding on tender grasses and shoots and buds of dwarf willow and birch. In the autumn the great majority travel southwards in large bands for hundreds of miles to the wooded areas, where they spend the winter feeding on mosses and lichens.

Without the caribou, large tracts of Canada would be practically uninhabitable, since the animal supplies the Indian and Eskimo with food, clothing, shelter, and means of obtaining supplies from the nearest trading post. The migratory movements, though very regular in point of time, are erratic as regards the route followed, and inability to strike the path of the migrating masses means very serious hardship for the tribes dependent upon this animal.

Effective conservation of this animal is therefore of the utmost importance.

On the other hand, the acquisition of rifles by native tribes has brought about a wasteful slaughter of the caribou. It has been already almost exterminated in northern and northwestern Alaska, and is in danger of a similar fate in Canada, unless effective conservation measures can be devised.

A rational system of animal conservation should not merely be passive; it should not confine itself to the enactment of legislative protection measures that are too often allowed to become a dead letter, but should include *active* measures that still tend toward an increase quantitatively and qualitatively in animal life. This can only be done by the creation of animal sanctuaries, definite reservations for animal life ranging in size from tracts of country down to artificial coppices in the public parks of urban districts. Within the bounds of such reservations, animal protection laws can be rigidly enforced. Outside the bounds the laws can be sufficiently relaxed to avoid hampering the agriculturist or the marketer of honest commodities.

In such sanctuaries, conditions should approximate as closely as possible to those of primeval woodland or prairie or swamp. Clean forestry is incompatible, for example, with animal profusion. Decayed and fallen trees, plentitude of brushwood, standing pools and meres should not merely be tolerated, but should be supplemented by artificial breeding facilities if possible. Further, there should be the fullest protection against the undue increase of wasteful predators.

This method of animal protection is one that is increasing.

The National Parks of the United States and Canada—Yellowstone, Yosemite, Sequoia, Wichita, Montana, Jasper, Rocky Mountains, Buffalo, Glacier, and the like—and the numerous State and Provincial game reserves are the finest of their kind in the world as regards extent and management.

Africa, once the home of the greatest aggregate of wild animal in the world, is rapidly losing its larger mammals and birds. The introduction of firearms, the introduction of such diseases as rinderpest, which in 1891 killed enormous numbers of game—particularly buffalo, giraffe, antelopes—in East Africa, the existence of native tribes dependent largely upon hunting, have all tended towards the reduction of the larger fauna. A convention of all the powers owning territory in Africa drew up regulations in 1900 to prevent unjustifiable slaughter of game ; the recommendations included the provision of game reserves, the establishment of closed seasons, restriction of the export of skins, horns, and tusks of certain forms, prohibition of particularly destructive hunting methods such as grass fires, pits, snares, and game traps ; many of these recommendations are in force, but the sheer impossibility of policing such enormous areas with the small forces available renders the enforcement of legislative measures difficult.

About twenty game reserves, comprising nearly 200,000 square miles, are to be found scattered over the Continent, mainly in British territories.

The discovery that the trypanosome parasites of sleeping sickness and cattle trypanosome diseases are harboured by wild game has, however, done much to strengthen a certain class of public opinion to whom the preservation of animal life is incomprehensible. Thus in 1920 there was an officially authorised butchery of wild game actually in a game preserve, the Umfalosi Reserve of Zululand, under the pretext of making the area "fly proof" for cattle ; needless to say, this object was not attained, but about 2,000 zebras, at least 1,000 head of other game, and four of the twelve much prized and long protected

remaining specimens of the white rhinoceros were slaughtered, and large numbers of game were scattered and driven further afield. It is, however, only fair to add that the original intention of the Zululand Game Drive was to drive the game from a no-man's land adjacent to European farms into the existing reserve, and the lack of discipline of shooters who continued to shoot after the reserve was reached was the reason for the unfortunate results which ensued.

In India there will be practically no large wild mammals and birds within a measurable space of time, except in preserves maintained by native chiefs or in the more inaccessible Government Forest Reserves.

India has not suffered much from the fur hunter, since few Indian animals have valuable fur, but on the other hand the bird fauna has suffered greatly from the depredations of the plumage hunter. The white egrets (*Herodias alba*, *intermedia*, and *garzetta*) have been hunted almost to extinction, and protective legislation has come into force almost too late to save them. In Burma the demands of the Chinese for rhinoceros horns has brought about an alarming decline in the numbers of the one-horned rhinoceros (*Rhinoceros unicornis*) and the Sumatran rhinoceros (*Dicerorhinus sumatrensis*); the Government has prohibited the shooting of these animals, but the difficulties of enforcing the prohibition are probably too great to render the enactment efficient.

In densely populated countries such as India and Burma, wild life is almost bound to dwindle in extent before the encroachments of agricultural settlement and the spread of cattle diseases.

In Australia vast damage is being done to smaller ground animals by the multiplication of introduced foxes and domestic cats. Only the larger kangaroos, the wombat, and the burrowing platypus seem able to hold their own. The demands of the fur trade, too, are tending to reduce the native fauna.

In Europe there are numerous sanctuaries of a smaller type, created chiefly for the protection of bird life. Germany and Great Britain, in particular, possess many such. In the latter country a recent movement has created many small bird sanctuaries, shelter coppices, and nesting facilities in the public parks of the cities, the Society for the Protection of Birds and the various Rambling Clubs having done much to influence public opinion. In the United States and Canada similar credit must be paid to Hornaday, Hewitt, and others, to the Audubon Societies, Camp Fire Clubs, and Game Protection Associations.

# PART IV

# BIBLIOGRAPHY

This bibliography of the more important books and articles and periodicals which deal with some aspect of Applied Zoology is arranged under the following headings :—

- General Applied Zoology.
- Medical and Veterinary Zoology.
- Agricultural and Horticultural Zoology.
- General Protozoology.
- Medico-veterinary Protozoology.
- Enteric Protozoa.
- Hæmatophilous Protozoa.
- General Helminthology.
- Flukes.
- Tapeworms.
- Roundworms.
- Soil Organisms.
- General Entomology.
- Medical, Veterinary, and Household Entomology.
- Agricultural Entomology.
- Forest Entomology.
- Insect Control.
- Vermin Repression.
- Bird Encouragement.
- Domesticated Animals.
- Horses.
- Cattle, Sheep, and Pigs.
- Domesticated Birds.
- Other Domesticated Animals.
- Bee-keeping.
- Silk and Lac Culture.
- Fisheries.
- Whaling and Sealing.
- The Fur Trade.
- Animal Conservation.

In order to economise space, each reference comprises only the author's surname, the date of publication, the title, and the town of publication.

References prior to 1906 are omitted, except when of particular historical interest, and the titles of short articles in periodicals are not included unless mentioned in the text or unless, again, the article is of particular historical interest. In these respects the bibliography is incomplete.

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